Geographical Variation in Nutritional Quality of White-tailed Deer Forage Plants in Louisiana

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Abstract: Land managers and researchers strive to understand factors influencing white-tailed deer (*Odocoileus virginianus*) populations and develop methods to improve habitat. Evaluating forage quality across variable habitat types and soil regions may assist land managers interested in improving habitat quality. We placed 570 plant sampling exclosures across nine primary habitat types in Louisiana and collected plant samples representing consumable forage from each exclosure during summer 2012. Each sample was dried and those with ≥10 g of dry matter were analyzed for crude protein, total digestible nutrients, and trace minerals to assess forage quality within each major habitat type across Louisiana. We also assessed potential relationships between crude protein, phosphorus, potassium, and calcium concentrations of preferred white-tailed deer forages in each habitat with 10-year averages of body mass and antler size for 4.5+ year-old male deer harvested in each habitat type. Samples collected from longleaf flatwoods habitats exhibited the poorest average nutritional quality, whereas samples from bottomland hardwood habitats generally had greatest nutritional value. We noted a significant correspondence in body mass and antler measurements of mature male deer among habitat types with forage calcium concentrations. We observed no significant relationships between body mass or antler measurements and any other measure of nutritional value among habitat types.

Key words: calcium, crude protein, forage, nutrition, *Odocoileus virginianus*, white-tailed deer

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White-tailed deer are selective foragers and consume a wide range of plant species. Deer typically select the most nutritious plants and portions of plants depending on the species available and their chemical or physical defenses (i.e., presence of plant secondary compounds or thorns) before consuming less nutritious plants. On average, deer consume 1,360 g of dry plant matter daily (Fowler et al. 1967) to meet basic nutritional needs. The levels of crude protein and digestible energy in forage are important dietary components and have been shown to have a positive relationship with the nutritional status of deer (Bahnak et al. 1979). Crude protein and energy vary seasonally in plants, often dependent on species and environmental conditions (Everitt and Gonzalez 1981, Schindler et al. 2004), as do a number of important trace minerals. Minerals commonly recognized as required for body maintenance and growth include calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), copper (Cu), manganese (Mn), and zinc (Zn), among others. Barnes et al. (1990) analyzed mineral content of various deer forages in southern Texas and found that forbs contained greater levels of Cu and Zn than grasses or woody browse. Conversely, woody browse contained less Fe, P, and K than forbs or grasses, and grasses displayed lower concentrations of Ca and Mg than woody browse or forbs. Although woody browse may at times be deficient in certain nutrients, it is suspected that deer can overcome lower amounts by becoming more selective in the food they consume and possibly using post-ingestive feedback cues to influence future food selection (Provenza 1995, Villalba et al. 2002).

Nutritional characteristics of forage plant species, such as crude protein, calcium, and phosphorus concentration, differ spatially and temporally according to soil region (Jacobson et al. 1977, Jones et al. 2008). In addition, the relative importance of differing forage species in the diet of deer varies across regions, even within states (Moreland 2005), Therefore, it is not surprising that body mass and antler development in male white-tailed deer vary across soil regions (Strickland and Demarais 2000, 2006) and habitat regions (Durham 2014).

Moreland (2005) identified nine primary habitat types for deer in Louisiana: Northeast Pine-Hardwood, Southeast Pine-Hardwood, Bottomland Hardwood, Upland Hardwood, Swamp Hardwood, Historic Longleaf, Longleaf Flatwoods, Coastal Prairie, and Coastal Marsh. Moreland (2005) then used browse surveys and rumen examinations across several decades to develop a list of plant species considered to be important for deer. The Louisiana Department of Wildlife and Fisheries (LDWF) annually evaluates forage conditions and use within these habitat types as part of their deer management program. However, the nutritional quality of the forage species found in these habitat types is not well understood.

Our objectives were to quantify the nutritional quality of plant species important to deer in Louisiana across the primary deer habitats delineated by Moreland (2005). We also sought to evaluate potential relationships between nutritional characteristics of forage plants stratified across the habitat types used by LDWF in their deer management program, and metrics of deer body and antler condition. We predicted that nutritional quality of forage plants would vary across habitat types and that nutritional characteristics of forage plants would relate to observed metrics of deer body and antler condition across Louisiana.

Methods

Study Sites

We selected study sites at state-operated Wildlife Management Areas (WMAs), national wildlife refuges, national forests, or private properties within each habitat region described by Moreland (2005; Figure 1). Bottomland hardwood sites were contained within the lower Mississippi Alluvial Valley and were generally poorly drained, hydric soils. Primary overstory species included sweetgum (*Liquidambar styraciflua*), green ash (*Fraxinus pennsylvanicus*), cottonwood (*Populus deltoids*), Nuttall oak (*Quercus texana*), black willow (*Salix nigra*), and sugarberry (*Celtis laevigata*). Pine hardwood habitats were found in the northwest and southeastern portions of the state, and ranged from rolling hills in the northwest to flatwoods habitats in the southeast. Overstory species included loblolly pine (*Pinus taeda*), red maple (*Acer rubrum*), hickories (*Carya* spp), oaks (*Quercus* spp.), blackgum (*Nyssa sylvatica*), and American beech (*Fagus grandifolia*). Upland hardwoods habitats were restricted to the loess blufflands and were characterized by steep bluffs and ravines. Overstory species included American beech, oaks, hickories, yellow-poplar (*Liriodendron tulipifera*), and eastern hophornbeam (*Ostrya virginiana*). Swamp hardwood habitats were found in the lower Atchafalaya floodplain and contained poorly drained hydric soils subjected to direct and backwater flooding. Overstory species included black willow, red maple, water tupelo (*Nyssa aquatic*), and bald cypress (*Taxodium distichum*). Historic longleaf habitats were found in west-central parts of the state, and contained well drained, sandy soils. Overstory species included longleaf pine (*P. palustris*), sweetgum, post oak (*Q. stellata*), and blackjack oak (*Q. marilandica*). Longleaf flatwoods habitats were found in the southeast of the state and were dominated by poorly drained soils with interspersed wetlands. Overstory species included longleaf pine, white titi (*Cyrilla racemiflora*), and wax myrtle (*Morella cerifera*). Coastal prairie and coastal marsh sites were restricted to areas along the Louisiana coast, with few canopy species on prairie sites. Marsh sites contained areas of marsh interspersed with black willow dominated forests on higher sites.

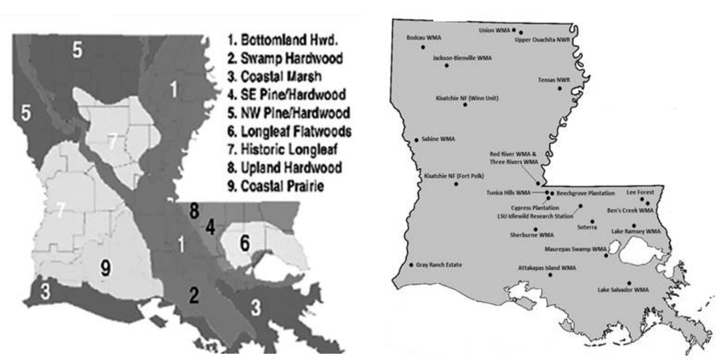

Figure 1. Illustration of a) primary habitat types for white-tailed deer in Louisiana as described by Moreland (2005), and b) location of study sites where vegetation samples were collected and analyzed for nutritional quality during 2012.

Additional descriptions of habitat types and vegetative characteristics of each study site can be found in Horrell (2013).

We selected more study sites within habitat types with greater deer productivity or deer harvest (i.e., Northwest and Southeast Pine-Hardwood and Bottomland Hardwood habitats) as these habitat types receive proportionally more emphasis by LDWF in the state's deer management program. We placed 1-m diameter circular exclosures across each of the nine different habitat types during 2011 at ≥40 m from roadways or access trails to avoid effects of edge habitat. Exclosures were constructed of 1.22-m high wire fencing with 10.16 × 10.16 cm openings to prevent deer from browsing new plant growth.

Within the Northwest and Southeast Pine-Hardwood habitat types, we placed 10 exclosures each within pine stands 1–5 years old, 6–15 years old, 16–24 years old thinned and without a burn history (no record of fire used to manage understory), 16–24 years old non-thinned and with a burn history (at least one prescribed fire had occurred), 25+ years old with a burn history, and 25+ years old without a burn history (Table 1). These conditions were chosen to ensure sampling occurred across the range of representative seral stages within that particular habitat type. We sampled each of these stand conditions at 3 study sites in the Northwest Pine-Hardwood habitat region and 2 sites in the Southeast Pine-Hardwood habitat type (for a total of 30 and 20 exclosures, respectively, in each stand condition).

Within the Bottomland Hardwood habitat type, we sampled stands aged 1–10, 11–20, 21–30, and 31+ years old at three study sites. All other habitats (Historic Longleaf, Longleaf Flatwoods, Upland Hardwood, Swamp Hardwood, Coastal Prairie, and Coastal Marsh) were sampled within a single stand condition because habitats on these study sites were dominated by a single seral stage. The Historic Longleaf, Upland Hardwood, and Swamp Hardwood habitats were sampled at two study sites with 20 exclosures each

Table 1. Number of plant exclosures sampled within primary deer habitats and strata in Louisiana during 2012.

Habitat type	Seral stage and stand description[a]	Number of exclosures
Northwest Pine-Hardwood	1–5	30
Northwest Pine-Hardwood	6–15	30
Northwest Pine-Hardwood	16–24 thinned, without burn history	30
Northwest Pine-Hardwood	16–24 non-thinned, with burn history	30
Northwest Pine-Hardwood	25+ with burn history	30
Northwest Pine-Hardwood	25+ without burn history	30
Southeast Pine-Hardwood	1–5	20
Southeast Pine-Hardwood	6–15	20
Southeast Pine-Hardwood	16–24 thinned, without burn history	20
Southeast Pine-Hardwood	16–24 non-thinned, with burn history	20
Southeast Pine-Hardwood	25+ with burn history	20
Southeast Pine-Hardwood	25+ without burn history	20
Bottomland Hardwood	1–10	30
Bottomland Hardwood	11–20	30
Bottomland Hardwood	21–30	30
Bottomland Hardwood	31+	30
Upland Hardwood		30
Swamp Hardwood		40
Historic Longleaf		40
Longleaf Flatwoods		20
Coastal Prairie		10
Coastal Marsh		10
Total		570

a. Numbers reference range of stand ages included in referenced strata.

(one study site in the Upland Hardwood habitat was an exception with only 10 exclosures due to small area of habitat available) since they were suspected to be less productive for deer than the Bottomland Hardwood and Pine-Hardwood habitats and more productive than Coastal Prairie and Coastal Marsh (each with one study site and 10 exclosures).

Data Collection and Analysis

After allowing new plant growth to occur during spring, we clipped only new plant growth from each exclosure, separated by species, to mimic forage selection by a concentrate selector like the white-tailed deer (Lashley et al 2014). We sampled study sites beginning in southern Louisiana in early May and ending in late June at northern sites to compensate for time since greenup. Sampling logistics required that plant samples be frozen prior to being dried for 72 hours in a forced-air oven at 60 C. Although freezing samples may affect some subsequent assays, crude protein and mineral concentrations are not affected by freezing samples (Undersander et al. 1993). Composite samples of species from each study site which met a required weight minimum of 10 g were sent to the Texas A&M University Soil, Water and Forage Testing Laboratory (College Station, Texas) for nutritional analysis. Due to the required weight minimum, samples of the same species collected from the same study site were combined to increase the number of samples which could be submitted. Likewise, we encountered instances where we did not collect 10 g of a particular species known to be forage plants for deer from within our exclosures on a particular study site. In these instances, we collected additional samples that did not show signs of browsing activity to reach the 10-g minimum.

Nutritional analyses included crude protein (CP) concentrations, dry matter (DM), and minerals (including Ca, P, Mg, K, Cu, Mn, and Zn). We calculated mean overall concentrations of minerals of all samples collected (ppm) to describe trends among habitats. We identified preferred deer forages within each habitat type described by Moreland (2005) according to S. Durham and D. Moreland (Louisiana Department of Wildlife and Fisheries, personal communication) and supported by published literature (Warren and Hurst 1981, Miller and Miller 1999, Edwards et al. 2004). We calculated mean CP, Ca, P, and K concentrations (%) of all preferred forages collected within each habitat type. If multiple samples of a species was obtained in any habitat type we used the mean value for that species across samples. We used linear regression to evaluate relationships between mean values of these nutritional parameters of preferred deer forages and measures of deer condition. To ensure an adequate sample size of sampled animals, we used 10-year averages of body mass and antler measurements (beam length and beam circumference) for 4.5+year-old male deer harvested in each habitat type (Coastal Prairie and Coastal Marsh were excluded due to small sample sizes of preferred species) from 2001–2010 for the Deer Management Assistance Program in Louisiana (Durham 2011, Durham et al. 2012).

Results

Pine-hardwood and hardwood-dominated habitats tended to have higher mean CP concentrations, whereas samples collected from longleaf and longleaf flatwood sites had the lowest CP concentrations (Table 2). Concentrations of P tended to be greatest in hardwood-dominated habitats and lowest in the longleaf-dominated sites (Table 3). Ca concentrations varied among habitats with the mean concentration in the bottomland hardwoods type being 2.8 times that observed in plants from the longleaf flatwoods. Similarly, other minerals varied among habitat types with lowest concentrations of Cu and Mn occurring in samples obtained from coastal marsh sites.

Because of the greater sampling intensity in the pine hardwood habitat types, as well as the greater diversity of stand conditions, we obtained samples of more species of preferred deer forages in these habitat types (Table 4). We had an insufficient number of preferred species sampled from the Coastal Prairie and the Coastal Marsh for further analysis. Mean CP concentrations in preferred forage species from the longleaf sites tended to be lower than those from other habitat types.

Linear regression analyses of CP, P, or K against mean body mass or antler measures of 4.5+ year-old male deer from each habitat type indicated no significant relationships ($R^2 \le 0.29$, $P \ge 0.18$). In contrast, we observed strong relationships between Ca concentrations and body mass ($R^2 = 0.93$, $P < 0.001$; Figure 2), antler base circumference ($R^2 < 0.57$, $P = 0.048$), and antler beam length ($R^2 = 0.73$, $P = 0.013$).

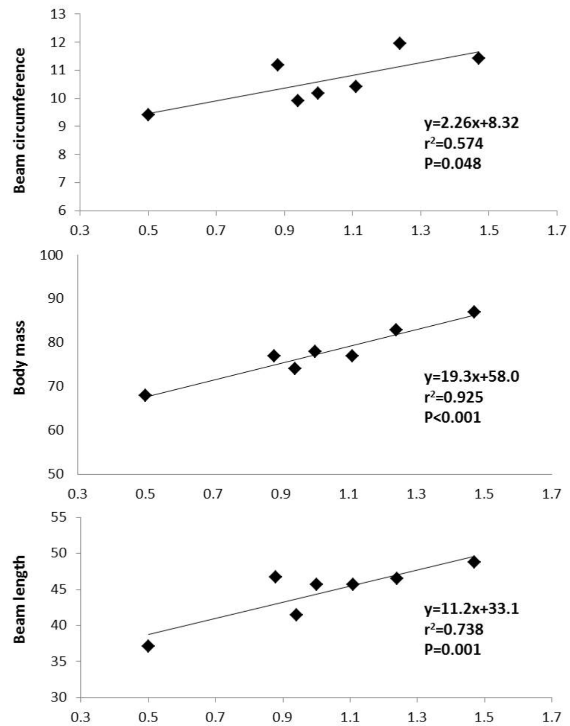

Figure 2. Regression analysis of relationship between calcium (Ca) concentrations (%) in preferred white-tailed deer forages in each deer habitat type during 2012 and 10-year averages of a) antler beam circumference (cm), b) body mass (kg), and c) antler beam length (cm) for 4.5+ year-old male deer harvested in each habitat type (except Coastal Prairie and Coastal Marsh) from 2001–2010 from the Louisiana Deer Management Assistance Program.

Table 2. Mean crude protein (CP) concentrations ±SE and range in CP across deer forage plants analyzed in nine habitat types in Louisiana during 2012.

Habitat type	CP (%)	SE	Range	Sample size
Swamp Hardwood	11.87	1.50	6.1 – 22.9	26
Upland Hardwood	10.37	0.82	5.8 – 16.4	30
Bottomland Hardwood	10.16	0.69	5.4 – 20.6	79
Southeast Pine-Hardwood	9.47	0.60	5.0 – 16.9	76
Coastal Prairie	9.43	1.30	4.6 – 19.5	21
Coastal Marsh	9.43	1.55	5.6 – 16.0	13
Northwest Pine-Hardwood	8.90	0.44	5.3 – 17.0	134
Longleaf Flatwoods	8.25	1.34	4.7 – 18.4	19
Historic Longleaf	7.43	0.78	3.5 – 12.8	39

Table 3. Mean concentration in ppm (±SE) of selected minerals present within all plant samples collected in each habitat type in Louisiana during 2012. Sample size represents the number of samples submitted for nutritional analysis. Abbreviated habitat types are: Northwest Pine-Hardwood (NWPH), Southeast Pine-Hardwood (SEPH), Bottomland Hardwood (BH), Historic Longleaf (HL), Longleaf Flatwoods (LF), Coastal Marsh (CM), Coastal Prairie (CP), Swamp Hardwood (SH), and Upland Hardwood (UH).

Habitat type	# Samples	Phosphorus	Potassium	Calcium	Magnesium	Zinc	Copper	Manganese
NWPH	134	1048 (117)	13745 (979)	9576 (1089)	2931 (280)	57 (13)	6.72 (0.83)	568 (105)
SEPH	76	1156 (156)	11135 (1299)	8118 (1446)	2771 (372)	50 (18)	6.91 (1.10)	812 (139)
BH	79	2727 (153)	17709 (1275)	14517 (1418)	3540 (366)	93 (17)	9.25 (1.08)	187 (136)
UH	30	2374 (248)	19266 (2069)	12518 (2302)	3300 (593)	84 (28)	8.94 (1.75)	346 (221)
SH	26	2965 (267)	22747 (2223)	10551 (2473)	3462 (636)	70 (30)	8.33 (1.88)	405 (238)
HL	39	881 (217)	18775 (1814)	8367 (2019)	2502 (520)	48 (25)	5.66 (1.54)	483 (194)
LF	19	982 (276)	14657 (1850)	5167 (913)	2058 (353)	70 (18)	6.53 (1.04)	754 (264)
CP	21	1240 (183)	10345 (1066)	9932 (2682)	3703 (778)	87 (20)	8.01 (1.10)	321 (124)
CM	13	1668 (344)	14262 (1874)	7830 (1564)	3237 (427)	60 (11)	3.09 (0.67)	115 (34)

Table 4. Mean crude protein (CP), phosphorus (P), potassium (K), and calcium (Ca) concentrations in preferred white-tailed deer forages in each deer habitat type during 2012 and 10-year averages of weights and antler measurements for 4.5+ year-old male deer harvested in each habitat type (except Coastal Prairie and Coastal Marsh) from 2001–2010 for the Deer Management Assistance Program in Louisiana.

		Nutritional parameter (%)				Body mass	Antler measurements	
Habitat type	Sample # species	CP	P	K	Ca	(kg)	Base	Length
Northwest Pine-Hardwood	39	9.10	0.11	1.39	1.00	78.5	10.16	45.72
Southeast Pine-Hardwood	22	9.56	0.11	1.08	0.88	77.1	11.18	46.74
Bottomland Hardwood	15	10.10	0.26	1.44	1.47	87.1	11.43	48.77
Upland Hardwood	8	10.50	0.24	1.59	1.24	82.6	11.94	46.48
Swamp Hardwood	6	10.89	0.27	1.74	0.94	73.5	9.91	41.40
Historic Longleaf	11	8.81	0.09	1.92	1.11	76.7	10.41	45.72
Longleaf Flatwoods	6	8.12	0.08	1.43	0.50	68.5	9.40	37.08

Discussion

Crude protein concentration is a commonly used measure of forage quality. However, minor variations in sample collection methods, sample handling, and laboratory analyses can limit direct comparisons among studies (Lashley et al. 2014), although comparisons of trends among studies may not be affected. For example, our results for CP were generally lower than those reported in other studies for the same species in Mississippi (Edwards et al. 2004, Iglay 2010), likely due to differences in sampling and analytical protocols or declines in CP concentrations that occur spring to summer (Jones et al. 2008) when the bulk of our sampling occurred. However, the regional trends in CP concentrations identified by Jones et al. (2008, 2010) were similar to those we observed across habitat types.

Based on regional CP concentrations, Jones et al. (2008) concluded that differences in nutritional planes among regions may be substantial enough to impact lactation success, fawn recruitment, and body growth and explain variation is deer morphometrics among soil-resource regions (Strickland and Demarais 2000). In contrast, although we observed similar differences in CP concentrations of forages among habitat types, we found no relationship between mean CP concentrations of preferred deer forages and body mass or antler measurements of 4.5+year-old males among habitats. Perhaps differences in CP requirements for lactation in does or body growth of young deer in comparison to CP requirements for mature males may explain these observed differences. Alternatively, Jones et al. (2008, 2010) only sampled 8 forage species across soil regions which did not account for differing availability of preferred forages and thus differences in deer diets across plant communities and regions. Our analyses included all deer forage species collected at sampling locations, the composition of which varied substantially among habitat regions.

Few data have been reported regarding mineral concentrations for many of the plant species we analyzed. Bottomland hardwood habitats appeared to have consistently greater levels of most minerals (particularly P, K, and Ca) than other habitat types, and an overall CP level among the greatest observed. This may be expected considering age-specific antler development is greater in bottomland hardwood than in the other habitat types in Louisiana (Moreland 2005). Samples collected from study sites in the bottomland hardwood, swamp hardwood, and upland hardwood habitat types were above the 2,500 ppm concentration of P determined by Ullrey et al. (1975) to be necessary for optimal growth in young deer. All other habitat types exhibited concentrations below 2,500 ppm, although each contained 1 or more species which exceeded the 1,400 ppm level deemed necessary for adult deer by Grasman and Hellgren (1993). For Ca, all habitat types except longleaf flatwoods had mean concentrations that exceeded the 4,000–5,100 ppm requirement for growing fawns listed by Ullrey et al. (1973).

Although CP is the most common nutrient evaluated when comparing forage quality for white-tailed deer, mineral concentrations, particularly Ca and P, have been shown to be directly related to measures of deer performance such as body growth, antler development, and reproductive fertility (see review by Jones and Hanson 1985). Our results clearly indicated a direct relationship between the average Ca concentration in preferred deer forages and variations in body mass and antler development of mature bucks. However, we did not observe a similar relationship between P concentrations and body mass or antler development. Grasman and Hellgren (1993) predicted that P limitation for antler growth is unlikely for adult browsing cervids. P demands for gestation and lactation are considerably more than for antler growth, and thus P requirements for female deer at these times may be greater.

Previous studies have similarly reported relationships between mineral availability and measures of deer performance. In Mississippi, Jacobson et al. (1977) evaluated the relationship between yearling male body mass, antler development, and doe fertility and selected soil fertility factors. Interestingly, they reported that yearling male body size was related to soil P and Ca levels. However, the relationship with soil P existed to 40 ppm beyond which there was no increase, whereas the relationship with soil Ca existed throughout the range of observed levels. Subsequently, Jones et al (2010) reported that across Mississippi, deer were larger at sites with greater Ca concentrations in some selected deer forages. However, Jones et al. (2010) used a considerably different sampling procedure than we employed. Whereas they selectively sampled 8 deer forages across soil resource areas in Mississippi, we sampled preferred deer forages based on availability across habitat regions in Louisiana. Despite the differing sampling procedure used in the 2 studies, the relationship between Ca concentrations and deer condition were similar. Relationships between soil Ca availability and deer body mass have also been reported in Wisconsin and Missouri (Jones and Hanson 1985), whereas Jones and Weeks (1998) suggested that macronutrient differences in Ca, Mg, and K may account for differences in body mass among areas in Illinois.

Management Implications

Our results suggest that not only does the availability of preferred deer forages differ among the predominant deer habitat types in Louisiana (Moreland 2005), but levels of important nutrients in these preferred forages can vary across habitat types. In our analysis, forage Ca concentrations were closely related to body mass and antler development of mature deer. Our findings suggest that in areas where patterns of these condition metrics do not meet hunter or landowner expectations, managers should consider investigating whether enhancement of Ca availability via agronomic plantings or habitat manipulations could positively influence male condition indices. We suggest additional research to evaluate the relationship between forage mineral availability and other measures of herd productivity, particularly potential relationships between P availability and female reproductive performance, neonatal fawn weights, and age-specific fawn body mass.

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