

Dietary Patterns of Sympatric Bobcats and Coyotes in Central Mississippi

Michael J. Chamberlain,¹ *Department of Wildlife and Fisheries,
Mississippi State University, Mississippi State, MS 39762*

Bruce D. Leopold, *Department of Wildlife and Fisheries, Mississippi
State University, Mississippi State, MS 29762*

Abstract: Bobcats (*Lynx rufus*) and coyotes (*Canis latrans*) are sympatric in many areas; however, this sympatry has evolved relatively recently in the southeastern United States with coyote range expansion. Where the 2 species are sympatric, habitat selection and diets of bobcats and coyotes may overlap. Knowledge of seasonal variation in prey selection is required to assess interspecific competition and understand factors facilitating coexistence between sympatric species, yet long-term (>5 years) information on sympatric diets is unavailable. We collected and analyzed 1,183 scats (591 bobcat, 592 coyote) from 1991–1997 in central Mississippi. Diet was assessed using frequency information and frequency-based correction factors to determine seasonal prey consumption. Coyote diets were dominated by white-tailed deer (*Odocoileus virginianus*), rabbits (*Sylvilagus* spp.), and fruits; whereas, bobcats consumed primarily rabbits and rodents. Deer comprised a large percentage of biomass consumed annually by both species, but was consistently higher for coyotes. Dietary overlap between the 2 carnivores varied seasonally, with lowest overlap during fall/winter. Our data suggest that bobcats may prey on mice in proportion to their availability. Coyote diets were more diverse than bobcats and, coupled with overlap estimates, suggest low interspecific competition between these sympatric species.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 53:204–219

Sympatric bobcats (*Lynx rufus*) and coyotes (*Canis latrans*) exhibit varying degrees of home range, habitat use, and dietary overlap (Witner and DeCalesta 1986, Major and Sherburne 1987, Edwards 1996). However, in many areas of the Southeast, this sympatry has occurred recently; hence, knowledge of interspecific associations is lacking. In northern latitudes, dietary studies conducted on sympatric bobcats and coyotes indicated that bobcats were more specialized than coyotes (Litvaitis and Harrison 1989). However, other studies reported similar diets between the 2 species

1. Present address: School of Forestry, Wildlife, and Fisheries, Louisiana State University, Baton Rouge, LA 70803.

(Witmer and DeCalesta 1986, Major and Sherburne 1987). Potentially similar diets coupled with extensive overlap in home range and habitat use patterns provides opportunity for interspecific interactions and similarities in prey selection; however, little information is available detailing seasonal dietary overlap.

Bobcat food habits have been widely studied and indicate that bobcats are carnivores, usually preying on rodents and lagomorphs throughout their range (Beasom and Moore 1977, Fritts and Sealander 1978, Miller and Speake 1978, Buttrey 1979, Edwards 1996). Similarly, dietary patterns of coyotes have been intensively examined and characterize the species as seasonally omnivorous (Litvaitis and Shaw 1980, Blanton 1988, Kelly 1991, Wagner 1993).

Many dietary studies relied on scat analyses which predominately used frequency data and a non-flesh component bias exists. These biases have been addressed using statistical models and correction factors (Kelly 1991, Kelly and Garton 1993, Wagner and Hill 1994); however, no studies have examined dietary patterns of sympatric bobcat and coyote populations using frequency-based correction factors based on feeding trials and consumption models. Knowledge of seasonal dietary overlap and prey selection, particularly using correction factors for biomass of prey consumed, is necessary to thoroughly understand bobcat and coyote population ecology and the sympatric relationships between these species.

Our objectives were to 1) determine and compare seasonal variations in diets of sympatric bobcat and coyote populations, 2) determine and examine annual variations in diet relative to trends in small mammal abundance, 3) examine and compare seasonal and annual differences in biomass and proportions of prey consumed, and 4) determine dietary overlap and diversity of seasonal prey selection for sympatric bobcat and coyote populations. Specifically, we tested the following hypotheses: 1) bobcats and coyotes exhibit seasonal interspecific differences in prey selection, 2) bobcat and coyote selection of small mammals as prey varies relative to abundance, 3) selection (i.e., occurrence in scat) of major prey items (deer, rabbits, mice, rats) varies seasonally, but not annually, and 4) dietary overlap and diversity differs seasonally and annually for sympatric bobcat and coyote populations in central Mississippi during 1991–1997.

We thank the following for assistance in data collection: J. G. Burton, T. H. Chamberlain, L. M. Conner, D. A. Edwards, T. Gehr, K. M. Hodges, C. D. Lovell, B. W. Plowman, and J. M. Ross. Special thanks to R. Andrus for considerable lab analyses. Technical advice was provided by B. T. Kelly. Editorial comments were provided by J. L. Bowman, L. M. Conner, and S. Demarais. Funding was provided by the Mississippi Department of Wildlife, Fisheries and Parks through Federal Aid in Wildlife Restoration, the National Wild Turkey Federation (NWTf), Mississippi Chapter of NWTf, Georgia-Pacific Corporation (GP), USDA Forest Service, and the Forest and Wildlife Research Center at Mississippi State University. This manuscript was approved as Journal Article WF108 of the Forest and Wildlife Research Center, Mississippi State University. We operated under Mississippi State University Institutional Animal Care and Use Committee Protocol 93–032.

Study Area

We conducted research on the Tallahala Wildlife Management Area (TWMA), a 4,900-ha area owned by GP adjacent to TWMA, and surrounding private lands. TWMA occupied 14,410-ha and was located within the Bienville National Forest in sections of Jasper, Newton, Scott, and Smith counties, Mississippi. TWMA contained 30% mature bottomland hardwood forests, 37% mature pine (*Pinus* spp.) forests, 17% mixed pine-hardwood forests and 16% 1- to 15-year-old loblolly pine (*P. taeda*) plantations. In 1992, a tornado bisected the area, altering nearly 1,000-ha of mature pine and hardwood forests. Following salvage of downed timber, the altered area was replanted to loblolly pine. GP land, managed primarily for wood fiber production, was composed mostly (90%) of 1- to 35-year-old loblolly pine plantations with the remainder in mixed pine/hardwood stands. Stand rotation averaged 35 years. Private lands were comprised mostly of mixed-pine/hardwood and short-rotation pine forests. Topography was gently to moderately rolling. TWMA hereafter refers to our entire study area, including GP and surrounding private lands.

Methods

Prey Sampling

We trapped small mammals annually on 25 permanent transects during early March 1993–1997. Transects were located in each major habitat type (mature bottomland hardwood, mature pine >30 years, mature mixed pine/hardwood, 0- to 8-year-old pine regeneration, 9- to 15-year-old pine regeneration, and 16- to 30-year-old pine regeneration) and measured 500 m long with stations located 20 m apart. Numbers of traps placed in each habitat type were proportional to the availability of that habitat type across TWMA. One rat and 1 mouse Victor snap-trap (Woodstream Corp., Lititz, Pa.) were placed at each station. Traps were prebaited for 3 days before being set for 4 days. Captured animals were identified to species and grouped either as rats [cotton rats (*Sigmodon hispidus*), marsh rice rat (*Oryzomys palustris*)], mice [white-footed, cotton mouse (*Peromyscus* spp.), golden mouse (*Ochrotomys nuttalli*), fulvous harvest mouse (*Reithrodontomys humulis*), housemouse (*Mus musculus*)] or shrews [least shrew (*Cryptotis parva*), southern short-tailed shrew (*Blarina brevicauda*)]. Numbers of small mammals and species captured/trapnight annually were determined and compared across years. Although small mammals were removed annually, we do not believe that prey availability was impacted as trapping only occurred 4 nights and was conducted on transects, rather than grids.

We used deer harvest data collected on TWMA to monitor and assess relative abundance of white-tailed deer (Roseberry and Woolf 1991). Numbers of deer harvested/hunter-day were compared across years to index relative change in deer population size. We compared numbers of rabbits harvested/hunter-day across years to provide baseline information on levels of rabbit populations.

Scat Collection and Analysis

Bobcat scat were collected during 1992–1997, whereas coyote scat were collected from 1991–1997. All scat were collected from roads and identified based on odor, shape, and tracks if present (Murie 1975). Only fresh (<1 week old) identifiable scat were collected. Scats were placed in paper bags and individually labeled with date, species, and location collected. Scats were air-dried, frozen, then thawed and oven-dried at 60–80 C for 48 hours to kill eggs of *Echinococcus* spp. (Colli and Williams 1972).

Material not considered part of each scat, primarily rocks and sand, was removed. Dried scats were placed in hand-sewn rip-stop nylon bags and soaked for 48 hours (Johnson and Hansen 1979). Following soaking, bags were kneaded to facilitate breakdown of the fecal matrix and washed in a washing machine until rinse water was clear. Scats were again dried at 60–80 C for 48 hours (Johnson and Hansen 1979, Kelly 1991, Wagner 1993). Contents of each bag were emptied into a metal pan and remains identified to species, if possible, using a reference collection at Mississippi State University compiled by Wooding (1984), Blanton (1988), Wagner (1993), and Edwards (1996). Keys to mammalian hair (Spiers 1973) and skulls (Glass 1951) were used when necessary.

Scat contents were analyzed following Kelly (1991) in program SCAT (Kelly and Garton 1993) and modifications outlined by Wagner (1993). Program SCAT estimates fresh mass of food items represented by remains of food items recovered in scat. SCAT uses a regression model (Kelly 1991) based on species-specific feeding trials to provide corrections for non-flesh components, percentage of a sample of scats in which a prey species occurred (Kelly 1991, Wagner 1993). Frequency of occurrence was defined as number of times a prey species occurred as a percentage of total number of occurrences for all prey species. Biomass of prey consumed and percentage of fresh weight (i.e., percentage of total biomass consumption) provided by program SCAT were determined seasonally. Seasons were defined as breeding/young-rearing (15 Jan–15 Aug) and fall/winter (16 Aug–14 Jan). Seasons were delineated to examine potential differences in seasonal prey utilization and to lessen biases associated with varying weights of larger prey (i.e., fawn vs. adult deer).

Our derivation of deer consumed using program SCAT varied depending on season. During breeding/young-rearing, we used fawn deer weights in models. Median fawn drop in Mississippi is 15 July and most fawns drop by 1 August (Jacobson et al. 1979). Further, most fawn mortality or depredation occurs between 30 and 60 days post-partum (Bowman et al. 1998). During breeding/young-rearing, the percentage of scat containing deer was lower relative to scat collected during fall/winter, and positive identification of adult deer remains in scat was rare (Fig. 1, 2). Thus, we believed that using fawn weights would better approximate consumption of deer by bobcats and coyotes.

Conversely, our fall/winter models included fawn and adult deer weights to develop a range of biomass estimates for deer consumption. We assumed that biomass estimates using fawn weights would better approximate consumption when partial

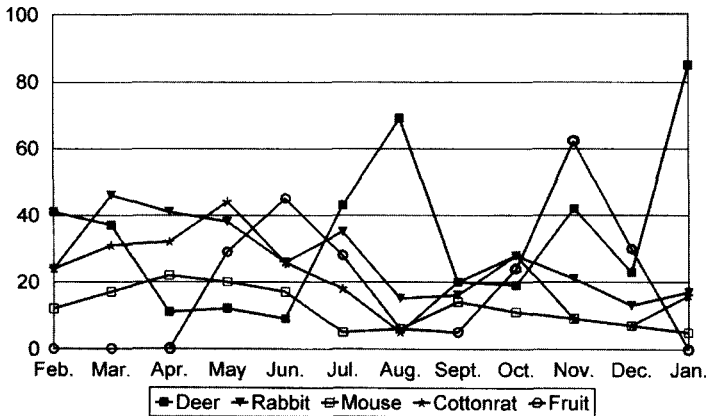


Figure 1. Percentage of coyote scat containing deer, rabbits, mice, cottonrats, and fruit by month on Tallahala Wildlife Management Area, Mississippi, 1991–1997.

deer carcasses (i.e., hunter-killed and discarded) were being consumed. However, we realize that carrion carcasses could have different amounts of non-digestible matter relative to digestible flesh than fawns. Thus, consumption estimates using fawn weights could be slightly inflated if coyotes and bobcats fed entirely on carcasses discarded by hunters. We determined adult deer weights using mean harvest weights on TWMA concurrent with this study and fawn weights using information from captive white-tailed deer at Mississippi State University (Bowman and Jacobson, unpubl. data). Similarly, weights of other prey items, including rodents, opossum (*Didelphis virginiana*), and raccoon (*Procyon lotor*) were determined using capture and harvest data from various species across TWMA (Lovell 1996, Burton 1998).

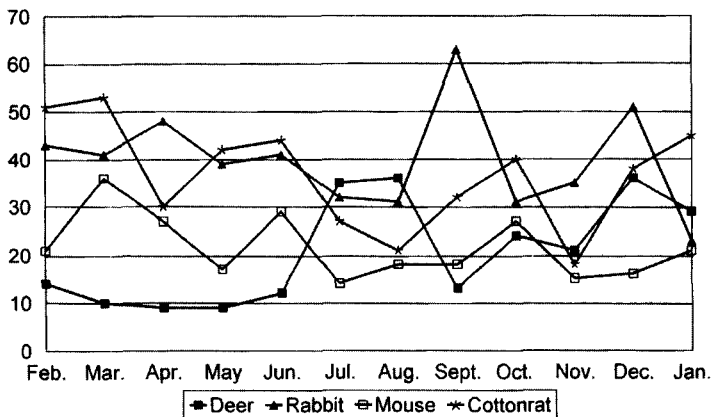


Figure 2. Percentage of bobcat scat containing deer, rabbits, mice, and cottonrats by month on Tallahala Wildlife Management Area, Mississippi, 1992–1997.

To test the hypothesis that occurrence of deer, rabbit, mice, and cottonrat would differ seasonally, but not annually, we developed a log-linear model (Fienberg 1977) to examine differences in occurrence of prey items in bobcat and coyote scat among years and between seasons. Within each scat, each prey item was coded as present or absent. Interactions between scat (occurrence) and season were used to determine significant differences in occurrence of each prey item between seasons when controlling for year effects. Likewise, interactions between scat and year were used to determine significant differences in occurrence of each prey item among years when controlling for season effects.

To examine relationships between use of small mammals and availability, we ranked occurrence of mice and rats in scat and relative abundance determined from snap-trapping from 1994–1997. A small sample size of scat during 1993 prevented comparisons for that year. Ranks for small mammal abundance were compared with ranks for occurrence to examine potential differences in use relative to availability.

We used Morisita's coefficient of overlap (Morisita 1959) to estimate dietary overlap by season within years and to test hypotheses concerning variable dietary overlap across seasons annually. Similarly, we examined the hypothesis that dietary diversity would vary seasonally by calculating a Shannon diversity index (Brower and Zar 1984). We used a Student's *t*-test (SAS Inst. 1992) to test differences in diversity between bobcats and coyotes among seasons within years. All tests were performed at $\alpha=0.05$.

Results

Prey sampling and relative abundance

We captured 1,207 small mammals in 23,340 trap nights from 1993–1997 using snap-traps and captures/trapnight varied from 0.02 to 0.07 across the study (Table 1). Small mammal abundance (total captures) declined from 1993–1996 before increasing in 1997. Annual deer harvest ranged from 205 to 350 and averaged

Table 1. Number of small mammals captured by category using snap-traps on permanent transects in 23,340 trap nights on Tallahala Wildlife Management Area, Mississippi, 1993–1997.

Species	Year				
	1993	1994	1995	1996	1997
Rats ^a	24	4	24	16	63
Mice ^b	332	188	177	102	177
Shrews ^c	28	2	12	1	16
Total captures	384	194	213	119	256
Total trapnights	5,000	5,000	4,000	4,440	4,900
Captures/trapnight	0.0768	0.0388	0.0533	0.0268	0.0522

a. *Sigmodon hispidus* and *Oryzomys palustris*.

b. *Peromyscus* spp., *Ochrotomys nuttalli*, *Reithrodontomys humulis* and *Mus musculus*.

c. *Blarina brevicauda* and *Cryptotis parva*.

277. Deer harvested/hunter-day varied slightly ($\bar{x}=0.05$, $SE=0.01$ deer harvested/hunter-day) and was highest during 1991 ($\bar{x}=0.08$, $SE=0.02$ deer harvested/hunter-day). Rabbits harvested/hunter-day was variable, with greatest harvest rate (3.0 rabbits harvested/hunter-day) in 1992–1993. Hunter effort was low for rabbits, with no effort reported in 1996, making conclusions regarding rabbit abundance during the study tenuous.

Bobcat diet

We collected and analyzed 591 bobcat scat from 1992–1997. We excluded fall/winter 1993 due to low sample sizes. White-tailed deer comprised the highest biomass of prey consumed, whereas rabbits and cottonrats dominated percentage of scat and occurred most frequently (Table 2). Other prey items identified in bobcat scat included: beaver (*Castor canadensis*), feral cat, various species of passerines, grass, opossum, armadillo (*Dasypus novemcinctus*), wild turkey (*Meleagris gallopavo*), snake, poultry, insects, raccoon, and squirrel (*Sciurus* spp.). Occurrence of deer ($\chi^2_1=1.56$, $P=0.212$), rabbits ($\chi^2_1=2.34$, $P=0.126$), cottonrats ($\chi^2_1=0.92$, $P=0.337$), and mice ($\chi^2_1=0.18$, $P=0.671$) did not differ between seasons. Similarly, occurrence of deer ($\chi^2_4=4.09$, $P=0.394$) did not vary with year. However, occurrence of rabbits ($\chi^2_4=20.39$, $P<0.001$), cottonrats ($\chi^2_4=21.29$, $P=0.001$), and mice ($\chi^2_4=12.32$, $P=0.015$) differed with year. Rat occurrence in scat was not ranked equal to abundance in any year; however, ranks for occurrence of mice in scat were similar to ranks for abundance of mice across all years.

Table 2. Frequency and biomass estimates of prey items represented in 591 bobcat scats collected on Tallahala Wildlife Management Area, Mississippi, 1992–1997.

Year	Season ^a	N	Prey items	N occur. ^b	% Scat ^c	% Occur. ^d	Biomass ^e	%FWP ^f
1992	BP	71	Deer	13	18.3	12.3	11.04	39.7
			Rabbit	31	43.7	29.3	7.51	27.0
			Cottonrat	38	53.5	35.9	5.95	21.4
			Mouse	13	18.3	12.3	1.32	4.8
			Other ^g	11	15.5	10.2	1.96	7.1
1993	BP	14	Deer	5	35.7	20.8	4.26	49.5
			Cottonrat	8	57.1	33.3	1.89	21.9
			Rabbit	4	28.6	16.7	1.67	19.4
			Mouse	5	35.7	20.8	0.34	4.0
			Other	2	14.1	8.3	0.45	5.2
1994	BP	25	Rabbit	10	41.7	21.3	2.76	25.8
			Cottonrat	14	58.3	29.8	2.50	23.4
			Deer	3	12.5	6.4	2.23	20.9
			Mouse	9	37.5	19.2	1.03	9.6
			Other	11	45.8	23.4	2.12	20.2
1995	BP	23	Deer	5	21.7	16.7	4.96	42.5
			Rabbit	14	60.9	46.7	4.83	41.4
			Cottonrat	4	17.4	13.3	0.64	5.5
			Mouse	4	17.4	13.3	0.40	3.4
			Other	2	13.0	6.7	0.83	7.2

Year	Season ^a	N	Prey items	N occur. ^b	% Scat ^c	% Occur. ^d	Biomass ^e	%FWP ^f
1996	BP	64	Deer	12	18.8	14.0	10.51	41.5
			Rabbit	27	42.2	31.4	7.23	28.5
			Cottonrat	25	39.1	29.1	4.52	17.9
			Mouse	11	17.2	12.8	1.18	4.7
			Other	11	17.3	12.8	1.87	7.4
1997	BP	161	Deer	30	18.6	14.2	25.90	35.9
			Rabbit	55	34.2	25.9	19.10	26.6
			Cottonrat	53	32.9	25.0	13.20	18.4
			Mouse	39	24.2	18.4	6.90	9.5
			Other	35	21.7	16.5	6.70	9.7
1992	FW	32	Deer	7	21.9	16.7	6.39–12.76	47.5–64.3
			Rabbit	13	40.6	31.0	3.34	24.8
			Cottonrat	14	43.8	33.3	2.56	19.0
			Mouse	6	18.8	14.3	0.80	5.9
			Other	2	6.3	4.7	0.37	2.8
1994	FW	25	Rabbit	9	36.0	19.6	2.09	17.2
			Cottonrat	12	48.0	26.1	2.37	19.5
			Deer	5	20.0	10.9	4.71–10.17	38.6–57.7
			Mouse	10	40.0	21.7	1.19	9.9
			Other	10	40.0	21.7	1.80	14.8
1995	FW	68	Deer	22	32.4	21.6	19.7–40.4	61.1–76.9
			Rabbit	38	55.9	37.3	6.92	21.5
			Cottonrat	22	32.4	21.6	3.57	11.1
			Mouse	11	16.2	10.8	1.42	4.4
			Other	9	13.3	8.8	0.61	1.9
1996	FW	45	Deer	7	15.6	12.7	6.60–13.6	39.6–58.8
			Rabbit	16	35.6	29.1	3.75	22.5
			Cottonrat	19	42.2	34.5	4.07	24.4
			Mouse	6	13.3	10.9	0.84	5.0
			Other	7	15.4	12.7	1.42	8.5
1997	FW	64	Deer	16	25.0	22.2	13.7–27.3	51.2–67.7
			Rabbit	16	25.0	22.2	4.38	16.4
			Cottonrat	14	21.9	19.4	3.47	13.0
			Mouse	14	21.9	19.4	2.37	8.9
			Other	12	18.8	16.7	3.12	10.4

a. BP=15 Jan–15 Aug. FW=16 Aug–14 Jan.

b. Number of occurrences for each respective prey item.

c. Percent of scats containing each respective prey item.

d. Percent of total occurrences for each respective prey item.

e. Estimated biomass in kilograms for each respective prey item. f. Estimated percent fresh weight consumed for each respective prey item.

g. Includes all other prey items.

Coyote diet

We collected and analyzed 592 coyote scat from 1991–1997. Similar to bobcat, we excluded fall/winter 1993 due to low sample sizes. White-tailed deer, rabbits, and fruits [blackberry (*Rubus* spp.) and persimmon (*Diospyros virginiana*)] comprised the highest percentage of scat and largest percentage fresh weight of prey consumed (Table 3). Other prey items identified in coyote scat included: grass, insects, snake, turtle, swine, various species of passerines, bobcat, squirrel, beaver, armadillo, wild turkey, feral cat, poultry, opossum, corn, cattle, acorns, and muskrat (*Ondatra zibethicus*). Occurrence of deer ($\chi^2_1 = 1.60$, $P = 0.206$) and mice ($\chi^2_1 = 1.18$, $P = 0.277$) did not differ between seasons. However, occurrence of rabbits ($\chi^2_1 = 6.55$, $P = 0.010$) and

cottonrats ($\chi^2_1=10.27$, $P=0.001$) varied between seasons. Occurrence of deer ($\chi^2_5=4.98$, $P=0.418$) did not differ with year. However, occurrence of rabbits ($\chi^2_5=14.92$, $P=0.011$), cottonrats ($\chi^2_5=19.10$, $P=0.002$), and mice ($\chi^2_5=15.52$, $P=0.008$) differed with year. Rat occurrence in scat was not ranked equal to abundance except in 1996 and ranks for mouse occurrence and abundance were not similar.

Table 3. Frequency and biomass estimates of prey items represented in 592 coyote scats collected on Tallahala Wildlife Management Area Mississippi, 1991–1997.

Year	Season ^a	N	Prey Items	N Occur. ^b	% Scat ^c	% Occur. ^d	Biomass ^e	% FWP ^f
1991	BP	22	Fruit ^g	12	54.5	36.4	5.15	35.1
			Deer	4	18.2	12.1	4.87	33.2
			Rabbit	6	27.3	18.2	1.44	9.8
			Blackberry/persim	4	18.2	12.1	1.01	6.9
			Other ^h	7	31.6	21.2	2.17	15.0
1992	BP	45	Deer	15	33.3	20.8	19.05	65.8
			Cottonrat	23	51.1	31.9	4.19	14.5
			Rabbit	14	31.1	19.4	2.59	9.0
			Blackberry/persim	11	24.4	15.3	1.08	3.7
			Other	9	19.9	12.5	1.99	6.9
1993	BP	21	Deer	10	47.6	28.6	10.66	68.6
			Rabbit	7	33.3	20.0	1.92	12.4
			Cottonrat	6	28.6	17.1	1.04	6.7
			Blackberry/persim	3	14.3	8.6	0.54	3.5
			Other	7	43.0	20.0	1.37	8.9
1994	BP	26	Deer	6	23.1	13.3	8.92	40.1
			Rabbit	13	50.0	28.9	5.17	23.3
			Cottonrat	9	34.6	20.0	1.72	7.7
			Blackberry/persim	1	3.8	2.2	0.06	0.3
			Other	16	61.3	35.6	6.35	28.8
1995	BP	28	Deer	10	35.7	23.3	8.49	44.1
			Rabbit	14	50.0	32.6	4.95	25.7
			Blackberry/persim	8	28.6	18.6	3.23	16.7
			Cottonrat	6	21.4	13.9	1.37	7.1
			Other	5	17.9	11.6	1.24	6.4
1996	BP	69	Deer	28	40.6	24.8	25.52	60.5
			Cottonrat	18	26.1	15.9	3.71	8.8
			Rabbit	14	20.3	12.4	3.66	8.7
			Blackberry/persim	17	24.6	15.0	3.46	8.2
			Other	36	52.2	31.9	5.78	13.8
1997	BP	133	Deer	33	24.8	18.3	45.25	43.2
			Rabbit	39	29.3	21.7	20.47	19.5
			Cottonrat	29	21.8	16.1	10.61	10.1
			Blackberry/persim	16	12.0	8.9	5.60	5.3
			Other	53	47.5	35.0	22.65	21.9
1991	FW	21	Fruit	3	14.3	10.3	0.79	6.4
			Deer	7	33.3	24.1	6.47–12.92	52.1–68.4
			Rabbit	3	14.3	10.3	1.08	8.7
			Blackberry/persim	8	38.1	27.6	2.21	17.7
			Other	8	38.1	27.6	1.87	15.1
1992	FW	39	Deer	6	15.4	9.5	10.88–21.74	39.4–56.5
			Cottonrat	7	17.9	11.1	1.68	5.9
			Rabbit	12	30.8	19.1	7.54	27.3
			Blackberry/persim	17	43.6	27.0	4.13	15.0
			Other	21	53.9	33.3	3.44	12.4

Year	Season ^a	N	Prey Items	N Occur. ^b	% Scat ^c	% Occur. ^d	Biomass ^e	% FWP ^f
1994	FW	19	Deer	11	57.9	36.7	7.73–15.9	61.0–76.3
			Rabbit	4	21.1	13.3	1.42	11.2
			Cottonrat	2	10.5	6.7	0.21	1.7
			Blackberry/persim	5	26.3	16.7	2.16	17.0
			Other	8	42.1	26.7	1.16	9.1
1995	FW	36	Deer	14	38.9	23.3	12.89–26.5	60.9–76.8
			Rabbit	12	33.3	20.0	4.23	20.0
			Blackberry/persim	9	25.0	15.0	1.22	5.8
			Cottonrat	12	33.3	20.0	1.27	6.0
			Other	13	36.1	21.7	1.56	7.4
1996	FW	69	Deer	21	30.4	18.4	20.2–41.5	55.7–74.9
			Cottonrat	14	20.3	12.3	2.59	7.1
			Rabbit	13	18.8	11.4	3.87	10.7
			Blackberry/persim	34	49.3	29.8	5.70	15.7
			Other	32	46.4	28.1	3.90	11.8
1997	FW	64	Deer	28	43.8	33.7	44.8–89.5	75.9–86.3
			Rabbit	11	17.2	13.3	4.49	7.6
			Cottonrat	7	10.9	8.4	1.65	2.8
			Blackberry/persim	22	34.4	26.5	4.25	7.2
			Other	15	23.5	18.1	3.79	6.5

a. BP=15 Jan–15 Aug, FW=16 Aug–14 Jan.

c. Number of scats containing for each respective prey item.

e. Estimated biomass for each respective prey item.

g. Includes grapes, cherry, muscadine (only identified during 1991 thus blackberry and persimmon used as category in subsequent years).

h. Includes all other prey items.

b. Number of occurrences for each respective prey item.

d. Percent of total occurrences for each respective prey item.

f. Estimated percent fresh weight consumed of each prey item.

Comparisons between bobcat and coyote diets

Morisita's similarity index indicated that bobcat and coyote diets were more similar during breeding/young-rearing than fall/winter (Table 4). Shannon diversity indices during breeding/young-rearing were higher for coyotes during 1993 ($t=2.32$, $P=0.024$), 1996 ($t=4.89$, $P<0.001$), and 1997 ($t=-3.34$, $P<0.001$), but not different in 1992 ($t=1.52$, $P=0.129$), 1994 ($t=0.465$, $P=0.643$), and 1995 ($t=0.733$, $P=0.467$). During fall/winter, diversity indices were higher for coyotes in 1992 ($t=5.07$, $P<0.001$), 1995 ($t=1.99$, $P=0.048$), and 1996 ($t=2.93$, $P=0.004$); higher for bobcats in 1994 ($t=-2.31$, $P=0.024$) and not different in 1997 ($t=0.202$, $P=0.840$).

Table 4. Seasonal indices to dietary overlap using Morisita's coefficient of overlap and corresponding Shannon diversity indices for bobcat and coyote diets on Tallahala Wildlife Management Area, Mississippi, 1992–1997.

Year	Bobcat		Coyote		Overlap	
	Breed/Young ^a	Fall/Winter ^b	Breed/Young ^a	Fall/Winter ^b	Breed/Young	Fall/Winter
1992	1.585	1.451	1.766	2.086	0.711	0.558
1993	1.583	N/A	1.973	N/A	0.660	N/A
1994	1.965	1.986	2.044	1.618	0.631	0.366
1995	1.486	1.609	1.600	1.823	0.676	0.708
1996	1.711	1.642	2.301	2.065	0.642	0.436
1997	1.935	1.942	2.222	1.922	0.729	0.432

a. Breeding/young-rearing season—15 Jan to 15 Aug.

b. Fall/winter—16 Aug to 14 Jan.

Discussion

Bobcats and coyotes displayed variable dietary overlap and often differential seasonal prey selection, suggesting that interspecific competition for resources was often low. Our data concurred with previous studies indicating that rodents (mice and cottonrats), rabbits, and deer most frequently occurred in bobcat diets (Beasom and Moore 1977, Miller and Speake 1978, Fritts and Sealander 1978, Matlack and Evans 1992), and that deer, rabbits, and fruit were important in coyote diets (Berg and Chesness 1978, Wooding 1984, Dibello et al. 1990, Wagner 1993). Additionally, our data suggested that other prey items were frequently consumed by both species, comprising a large proportion of the diet during some seasons during our study. Bobcats and coyotes on TWMA exhibited habitat partitioning (Edwards 1996, Lovell 1996) and rarely interacted temporally or spatially (Edwards 1996). Further, coyotes on TWMA often hunted in groups (Edwards 1996). Hence, we suggest that differences in hunting behavior, prey selection, and foraging efficiency by each species resulted in observed differences in dietary patterns and influenced estimates of prey consumption.

Bobcats and coyotes depredated white-tailed deer fawns (Cook et al. 1971, Carroll and Brown 1977, Labisky and Boulay 1998). However, coyotes and felids in general will readily scavenge carcasses when available (Nellis and Keith 1968, Berg and Chesness 1978, Hilton 1978). Further, previous researchers have suggested that increasing occurrences of deer in scats during fall/winter periods were likely coyotes and bobcats scavenging deer carcasses, rather than directly taking deer (Hilton 1978, Wooding 1984, Edwards 1996). Private lands surrounding TWMA contained several areas where deer remains and carcasses were discarded; hence deer carcasses were consistently available to bobcats and coyotes throughout the study. Additionally, given the temporal distribution of deer occurrence within scat of both species (Fig. 1, 2), our data supported contentions that much deer consumption during fall/winter was indeed carrion. Although much deer consumed by bobcats was potentially carrion, bobcats may feed less on carrion carcasses than carcasses they have killed (McCord 1974), thus having profound implications on the amount of remains identified in scat. Conversely, social foraging by coyotes likely results in more immediate depletion of kills or carcasses, particularly given the higher consumption rates and opportunism in coyotes relative to bobcats (Kelly 1991, VanDomelen 1992). Under either foraging scenario, our data suggested that white-tailed deer, whether directly killed or consumed as carrion, were important food items to coyotes and bobcats.

Beasom and Moore (1977) reported that deer occurred more frequently in bobcat diets when rabbit and cottonrat populations were depressed. Similarly, Matlack and Evans (1992) reported that deer and small mammals occurred more frequently in bobcat diets when hare populations were low. Our data indicated that occurrence of deer in scats was consistent across years, suggesting that deer were a consistently important prey item of coyotes and bobcats on TWMA. VanDomelen (1992) reported that deer flesh provided more energy and nitrogen to bobcats than cottonrats

or rabbits. Thus, energetically it may be advantageous for bobcats to consume deer consistently in the presence of other prey items, particularly females following depletion of body reserves post-partum and lactation during summer (Litvaitis et al. 1986). Similarly, fawns may be specifically sought by coyotes raising weaned, rapidly growing young (Harrison and Harrison 1984). As the deer population was relatively stable on TWMA, consistent use of deer by coyotes and bobcats likely resulted from relatively stable deer populations and reliable availability of fawns and carrion across years.

Although percentage of scat and frequency of occurrence were useful for between-species comparisons and overlap estimates, we realized biomass estimates of white-tailed deer consumed by bobcats were potentially biased. Feeding trials conducted by Baker (1991) used for model development within SCAT did not include digestibility or feeding information on prey larger than lagomorphs (i.e., 4.5 kg). Thus, biomass estimates of deer consumed by bobcats were beyond bounds of the regression model and should be interpreted with caution. Further, given that bobcats may consume carrion less relative to direct kills (McCord 1974), it is unclear how day-to-day and individual variation may affect consumption (biomass) estimates when carrion is readily available. However, regardless of model precision, our data represented a crude estimate of deer consumption by bobcats in sympatry with coyotes, information previously unavailable in our region. Percentage of scat and occurrence of deer in bobcat scat was consistently lower than in coyote scat, indicating deer were consumed less relative to consumption by coyotes. However, percentage of scat and occurrence of deer consistently equaled or exceeded that of mice in bobcat scat, further supporting the importance of deer in bobcat diet on TWMA.

Although bobcats rarely consumed fruits, percentage of coyote scat containing fruit was often great, but seasonal, reflecting availability of those fruits (Fig. 1). Coyotes often feed on blackberries and persimmons (Wooding 1984, Wagner 1993, Edwards 1996). Andelt et al. (1987) reported that persimmons were selected by coyotes in Texas and suggested that selection of persimmons may buffer deer fawns from predation. On TWMA, coyotes consumed large proportions of persimmons relative to other food items during October and November. As populations of cottonrats and other rodents are near peak levels during this period (Odum 1955) and deer carrion increases with the onset of sport hunting seasons in October, our data suggested that coyotes indeed selected persimmons when available. Locating and consuming fruits may require less relative energy relative to searching for alternate prey; hence, coyotes likely improve foraging efficiency by shifting prey selection when fruits are abundant (MacArthur and Pianka 1966, Norbert 1977).

Interspecific comparisons of prey items consumed revealed that the proportion of mice and cottonrats taken by bobcats was consistently higher than for coyotes. Our data indicated that occurrence of mice in coyote scat varied across years, suggesting that coyotes did not prey on mice in proportion to availability. Although certainly not cause and effect, similarities in rankings of mice occurrence and abundance suggested that bobcats were better able to exploit mice than

coyotes and may prey on mice relative to availability. Also, as suggested by Cypher and Spencer (1998), coyotes may indeed be limited in their ability to exploit smaller rodents relative to other carnivores. Similarly, variable occurrence of cottonrat in coyote scat and consistently lower occurrence during fall/winter indicated that coyotes may not be able to efficiently exploit cottonrats, particularly during years of low abundance. Furthermore, coyotes may be less efficient at capturing cottonrats than bobcats.

Sympatric bobcat and coyote populations on TWMA exhibited variable dietary overlap. Coyotes often shift dietary patterns relative to prey declines, exhibiting strong omnivory and using alternate resources to withstand environmental stresses (Todd 1985, Cypher and Spencer 1998). Similarly, although strongly carnivorous, bobcats may shift prey selection when populations of rodents and rabbits decline (Beasom and Moore 1977). Coyotes and bobcats may share very similar diets; however, coyotes on TWMA, similar to many other regions, exploited fruits (Leopold and Krausman 1986). When bobcats and coyotes exploit similar prey items as their major source of food, significant resource competition may result (Major et al. 1986). Although both species preyed frequently on deer and rabbits on TWMA, we suggest that competition for resources was low, likely the function of differential foraging efficiency and prey selection, omnivory in coyotes, and habitat partitioning.

Management Implications

Bobcats on TWMA were strongly carnivorous, whereas coyotes were seasonally omnivorous. Given these differences in prey selection and previous findings of habitat partitioning between the species (Lovell 1996, Edwards 1996), our data suggested that sympatric bobcat and coyote populations on TWMA displayed low inter-specific competition for resources. Both species consistently consumed white-tailed deer throughout the study, indicating the importance of deer as a food item. However, based on harvest information, white-tailed deer populations did not decline during the study. If increasing occurrence of deer in fall/winter diets was a function of increased availability of carrion, bobcat and coyote consumption of deer may be a direct function of hunter harvest. Given the strong selection of persimmons by coyotes, we suggest managers consider landscape availability of fruits when assessing coyote depredation of deer. Based on previous research and our data, increasing fruit availability during fawning periods may indeed serve to buffer fawn depredation (Andelt et al. 1987).

Although we realize that many factors may influence prey consumption and hence, consumption estimates, we suggest researchers consider using prey consumption models when examining dietary patterns. We recognize current limitations in the bobcat model presented in SCAT (Kelly and Garton 1993), indicating a need for research addressing these limitations. Researchers should consider using consumption models when assessing prey selection of bobcats and coyotes, particularly when attempting to quantify consumption of prey species and develop carnivore management programs.

Literature Cited

- Andelt, W. F., J. G. Kie, F. F. Knowlton, and K. Cardwell. 1987. Variation in coyote diets associated with season and successional changes in vegetation. *J. Wildl. Manage.* 51:273–277.
- Baker, L. A. 1991. Feeding ecology of reintroduced bobcats on Cumberland Island, Georgia. M.S. Thesis, Univ. Ga., Athens. 110pp.
- Beasom, S. L. and R. A. Moore. 1977. Bobcat food habit response to a change in prey abundance. *Southwest. Nat.* 21:451–457.
- Berg, W. E. and R. A. Chesness. 1978. Ecology of coyotes in northern Minnesota. Pages 229–248 in M. Bekoff, ed. *Coyotes: biology, behavior, and management*. Acad. Press, New York, N.Y. 384pp.
- Blanton, K. M. 1988. Summer diet of coyotes in the southeast, and the response of coyotes to siren surveys. M.S. Thesis, Miss. State Univ., Mississippi State. 82pp.
- Bowman, J. L., H. A. Jacobson, and B. D. Leopold. 1998. Fawn survival on Davis Island, Mississippi, after an early summer flood. *Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies* 52:397–402.
- Brower, J. E. and J. H. Zar. 1984. Field and laboratory methods for general ecology. 2nd ed. William C. Brown Publ., Dubuque, Iowa. 226pp.
- Burton, J. G. 1998. Population estimates and indices for selected medium-sized carnivores in central Mississippi. M.S. Thesis, Miss. State Univ., Mississippi State. 194pp.
- Buttrey, G. W. 1979. Food habits and distribution of the bobcat, *Lynx rufus rufus* (Schreber), on the Catoosa Wildlife Management Area. Pages 87–91 in *Research Conference Proceedings*. Front Royal, Va. 137pp.
- Carroll, B. K. and D. L. Brown. 1977. Factors affecting neonatal fawn survival in south-central Texas. *J. Wildl. Manage.* 41:63–69.
- Colli, C. W. and J. F. Williams. 1972. Influence of temperature on the infectivity of eggs of *Echinococcus granulosus* in laboratory rodents. *J. Parasit.* 58:422–426.
- Cook, R. S., M. White, D. O. Trainer, and W. C. Glazener. 1971. Mortality of young white-tailed deer fawns in south Texas. *J. Wildl. Manage.* 35:47–56.
- Cypher, B. L. and K. A. Spencer. 1998. Competitive interactions between coyotes and San Joaquin kit foxes. *J. Mammal.* 79:204–214.
- Dibello, F. J., S. M. Arthur, and W. B. Krohn. 1990. Food habits of sympatric coyotes, *Canis latrans*, Red foxes, *Vulpes vulpes*, and bobcats, *Lynx rufus*, in Maine. *Can. Field-Nat.* 104:403–408.
- Edwards, D. A. 1996. Ecological relationships among bobcats, coyotes, and gray foxes in central Mississippi. M.S. Thesis, Miss. State Univ., Mississippi State. 182pp.
- Fienberg, S. E. 1977. *The analysis of cross-classified data*. MIT Press, Cambridge, Mass. 151pp.
- Fritts, S. H. and J. A. Sealander. 1978. Diets of bobcats in Arkansas with special reference to age and sex differences. *J. Wildl. Manage.* 42:533–539.
- Glass, B. P. 1951. *A key to the skulls of North American mammals*. Dep. Zool., Okla. Agric. and Mechanical Coll., Stillwater. 54pp.
- Harrison, D. J., and J. A. Harrison. 1984. Foods of adult Maine coyotes and their known-aged pups. *J. Wildl. Manage.* 48:922–926.
- Hilton, H. 1978. Systematics and ecology of the eastern coyote. Pages 210–228 in M. Bekoff, ed. *Coyotes: biology, behavior, and management*. Acad. Press, New York, N.Y. 384pp.

- Jacobson, H. A., D. C. Guynn, R. N. Griffin, and D. Lewis. 1979. Fecundity of white-tailed deer in Mississippi and periodicity of corpora lutea and lactation. *Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies* 33:30–35.
- Johnson, M. K. and R. M. Hansen. 1979. Estimating coyote food intake from un-digested residues in scats. *Am. Midl. Nat.* 702:363–367.
- Kelly, B. T. 1991. Carnivore scat analysis: An evaluation of existing techniques and the development of predictive models of prey consumed. M.S. Thesis, Univ. Idaho, Moscow. 217pp.
- and E. O. Garton. 1993 Program SCAT 1.0 Dep. Wildl., Univ. Idaho, Moscow.
- Labiscky, R. F. and M. C. Boulay. 1998. Behaviors of bobcats preying on white-tailed deer in the Everglades. *Am. Midl. Nat.* 139:275–281.
- Leopold, B. D. and P. R. Krausman. 1986. Diets of 3 predators in Big Bend National Park, Texas. *J. Wildl. Manage.* 50:290–295.
- Litvaitis, J. A. and J. H. Shaw. 1980. Coyote movements, habitat use, and food habits in southwestern Oklahoma. *J. Wildl. Manage.* 44:62–68.
- , A. G. Clark, and J. H. Hunt. 1986. Prey selection and fat deposits of bobcats (*Felis rufus*) during autumn and winter in Maine. *J. Mammal.* 67:389–392.
- and D. J. Harrison. 1989. Bobcat-coyote niche relationships during a period of coyote population increase. *Can. J. Zool.* 67:1180–1188.
- Lovell, C. D. 1996. Bobcat, coyote, and gray fox micro-habitat use and interspecies relationships in a managed forest in central Mississippi. M.S. Thesis, Miss. State Univ., Mississippi State. 162pp.
- MacArthur, R. H. and E. R. Pianka. 1966. On optimal use of a patchy environment. *Am. Nat.* 100:603–609.
- Major, J. T. and J. A. Sherburne. 1987. Interspecific relationships of coyotes, bobcats, and red foxes in western Maine. *J. Wildl. Manage.* 51:606–616.
- , ———, J. A. Litvaitis, and D. J. Harrison. 1986. Resource use and interspecific relationships between bobcats and other large mammalian predators in Maine. Page 291 in S. D. Miller and D. D. Everett, eds. *Cats of the world*. Natl. Wildl. Fed., Washington, D.C.
- Matlack, C. R. and A. J. Evans. 1992. Diet and condition of bobcats, *Lynx rufus*, in Nova Scotia during autumn and winter. *Can. J. Zool.* 70:1114–1119.
- McCord, C. M. 1974. Selection of winter habitat by bobcats (*Lynx rufus*) on the Quabbin Reservation, Massachusetts. *J. Mammal.* 55:428–437.
- Miller, S. D. and D. W. Speake. 1978. Prey utilization by bobcats on quail plantations in southern Alabama. *Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies* 32:100–111.
- Morisita, M. 1959. Measuring of interspecific association and similarity between communities. *Memoirs Faculty of Kyushu University. Series F.* 3:65–80.
- Murie, O. J. 1975. A field guide to animal tracks. 2nd ed. Houghton Mifflin Co., Boston, Mass. 375pp.
- Nellis, C. H. and L. B. Keith. 1968. Hunting activities and success of lynxes in Alberta. *J. Wildl. Manage.* 32:718–722.
- Norberg, R. A. 1977. An ecological theory on foraging time and energetics and choice of optimal food-searching method. *J. Anim. Ecol.* 46:511–529.
- Odum, E. P. 1955. An eleven-year history of a *Sigmodon* population. *J. Mammal.* 36:368–378.
- Roseberry, J. L. and A. Woolf. 1991. A comparative evaluation of techniques for analyzing white-tailed deer harvest data. *Wildl. Mono.* 117. 59pp.

- SAS Institute. 1992. SAS/STAT User's Guide. Vers. 6, 4th ed. SAS Inst., Inc. Cary, N.C. 1,686pp.
- Spiers, J. K. 1973. A microscopic key to the hairs of Virginia land mammals. M.S. Thesis, Virginia Tech, Blacksburg, Va. 106pp.
- Todd, A. W. 1985. Demographic and dietary comparisons of forest and farmland coyote, *Canis latrans*, populations in Alberta. Can. Field Nat. 99:163-171.
- Wagner, G. D. 1993. Coyote diet in areas of wild turkey abundance during the wild turkey reproductive season. M.S. Thesis, Miss. State Univ., Mississippi State. 144pp.
- and E. P. Hill. 1994. Evaluation of southeastern coyote diets during the wild turkey reproductive season. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 48:173-181.
- Witmer, G. W. and D. S. DeCalesta. 1986. Resource use by unexploited bobcats and coyotes in Oregon. Can. J. Zool. 64:2333-2338.
- Wooding, J. B. 1984. Coyote food habits and the spatial relationship of coyotes and red foxes in Mississippi and Alabama. M.S. Thesis, Miss. State Univ., Mississippi State. 43pp.
- VanDomelen, E. D. 1992. Nutrition, prey assimilation, and bioenergetics of captive bobcats. M.S. Thesis, Miss. State Univ., Mississippi State. 144pp.