Bobcat Prey Digestibility and Representation in Scats

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Abstract: Nine bobcats (*Felis rufus*) trapped from the Coastal Plain of Georgia in fall 1989 were fed weighed amounts of cotton mice (*Peromyscus gossypinus*), hispid cotton rats (*Sigmodon hispidus*), eastern grey squirrels (*Sciurus carolinesis*), domestic rabbits, a juvenile feral hog (*Sus scrofa*), and adult white-tailed deer (*Odocoileus virginianus*) to develop correction factors to convert mass of prey remains in scats to an estimate of mass of prey consumed for different prey types. Dry matter digestibility increased with increasing prey size except for white-tailed deer. For prey under 4.5 kg, we developed a regression equation ($r^2 = 0.75$, $P < 0.0001$) to estimate correction factors for different sizes of prey. With this information, percent biomass consumed of different prey species in bobcat diets can be estimated from remains in bobcat scats.

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In studies of predators and predator-prey relationships attention has been increasingly focused on methods for accurately estimating the diets of carnivores from scat analysis (Floyd et al. 1978, Johnson and Hansen 1979, Weaver and Hoffman 1979, Corbett 1989, Gamberg 1989, Kelly 1991). There are 2 traditional methods of reporting scat analysis results: (1) frequency of occurrence, calculated as the percent of all scats in which a prey type was found, and (2) percent occurrence, calculated as the number of times a prey type occurs divided by the total number of all prey occurrences. In these methods of scat analysis, larger prey items are underrepresented and smaller items overrepresented in scats relative to

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their actual consumption in the diet (Murie 1946, Lockie 1959, Mech 1970, Weaver and Hoffman 1979). Smaller prey items are composed of proportionately more indigestible material (i.e., hair, teeth, bones) than larger prey; consequently smaller prey items have a greater representation in scats per unit ingested than larger prey (Floyd et al. 1978).

To correct this bias, researchers have conducted feeding trials to determine the mass of prey consumed per scat or per gram of remains for different sizes of prey (Floyd et al. 1978, MacCracken and Hansen 1982, Ackerman et al. 1984, Kelly 1991). Multiplying the weight of remains of a prey type by the ratio of grams consumed per gram excreted or per scat for that prey type produces an estimate of the number of grams consumed. The use of correction factors to calculate estimates of biomass consumed from the amount of remains in scats is an established technique in carnivore scat analysis (Lockie 1959, Floyd et al. 1978, Johnson and Hansen 1979, Liberg 1982, Ackerman et al. 1984, Gamberg 1989, Corbett 1989, Maehr et al. 1990, Kelly 1991).

Several researchers have followed the lead of Floyd et al. (1978) in developing regression equations to predict correction factors for coyotes (*Canis latrans*), and cougars (*Felis concolor*) (MacCracken and Hansen 1982, Ackerman et al. 1984, Kelly 1991). These regression equations are based on the assumptions that digestibility of a prey type is closely related to the size of prey, and that digestibility of a prey type to a specific carnivore species does not change (Floyd et al. 1978).

The purpose of this study was to develop an equation to predict prey consumed per gram of remains in scats for bobcats, using a modification of the methods reported by Floyd et al. (1978) for wolves. We also assumed the amount of a prey type consumed per gram of remains in scats was closely related to the size of prey. To test this assumption, we examined the dry matter digestibility of prey consumed by bobcats in our feeding trials. We analyzed bobcat scats collected in the field using frequency of occurrence and percent estimated biomass consumed to demonstrate the possible magnitude of differences in results between the 2 techniques.

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Methods

Bobcats were trapped from the Coastal Plain of Georgia using foothold traps in fall 1989. Bobcats were placed individually in cages and maintained in captivity for up to 1 month. Cages were 1.8 x 1.2 x 1.2 m, constructed of 2.4- x 4.8-cm wire mesh, and raised 0.6 m above the ground. We placed wooden boxes inside the cages and hung sheet metal under the cages to collect urine and feces. Water was available *ad libitium*. Cages were placed in a corrugated-metal pole barn ventilated with fans and exposed to indirect natural light.

Feeding trials were conducted from September through mid-December 1989. We conducted 18 feeding trials using 6 different prey types: cotton mice, hispid cotton rats, eastern grey squirrels, domestic rabbits, juvenile feral hog, and adult white-tailed deer. We completed 2–5 trials per prey species (Table 1). For each feeding trial, a bobcat was fed a chicken, fasted for 48 hours, and then offered a weighed amount of a single prey type. The amount not consumed, if any, was collected after 48 hours and weighed. The bobcat was fed another chicken 72 hours after the trial prey was offered. All scats occurring between the disappearance of chicken feathers in scats at the beginning of the trial and the reappearance of feathers in scats at the end of the trial were considered to be undigested remains of the trial. Scats were collected daily and frozen. We used 6 adult male bobcats (8.02 ± 1.71 kg, $\bar{x}$ ± SD) 2 adult females (6.35 ± 0.49 kg), and 1 juvenile female (3.3 kg). The juvenile female was used in 1 feeding trial with cotton mice.

Trials using cotton mice and hispid cotton rats consisted of multiple whole individuals. Enough individuals were used so that at least 200 g of prey were presented to the bobcat. Eastern grey squirrels ($\bar{x}$ = 410 g) and domestic rabbits ($\bar{x}$ = 3,070 g) were fed as entire single individuals. Because of cage size limitations,

Table 1. Mean fresh mass, percent dry mass, number of trials, and dry matter digestibility for prey species used in captive bobcat feeding trials, 1989.

			Digestibility %		
Species	Mass (kg)	DM (%)	*N*	$\bar{x}$	SD
Feral hog	4.48	31.9	2	90.9A[a]	0.7
Domestic rabbit	3.07	31.6[b]	3	89.0AB	1.8
White-tailed deer	35.60[c]	27.8	3	86.3ABC	3.2
Grey squirrel	0.41	33.3[d]	2	82.5ABC	4.2
Hispid cotton rat	0.09[e]	32.6[b]	5	81.6BC	6.1
Cotton mouse	0.03[e]	32.6[b]	3	78.9C	4.9

[a] Means with the same letters are not different ($P > 0.05$); Duncan's Multiple Range Test.

[b] From values reported for similar species in Powers et al. 1989 and Litvaitis and Mautz 1980.

[c] From Georgia Department of Natural Resources, Game and Fish Division, Game Management Section. Georgia's wildlife surveys 1982–1983.

[d] From Powers et al. 1989.

[e] From Golley 1962.

the juvenile feral hog was halved, and the front and rear portions fed to the bobcats. The white-tailed deer were fed as portions weighing at least 2,000 g. These portions consisted of either hindquarters, shoulders, or thorax and abdomen. Portions of hogs and white-tailed deer were presented with bones and hide intact.

Scats were oven-dried at 60° C for at least 72 hours, weighed, and components separated by hand. Hair in the scats was identified macroscopically, and microscopically if necessary, using length, color, texture, and medullary characteristics (Spiers 1973). For microscopic examination, guard hairs were selected from a scat, washed in methyl salicylate, and mounted on slides. Guard hairs were identified using Spiers' (1973) key and by comparison to known specimens. Other mammalian remains (teeth and nails) were identified by comparison to known specimens. If more than 1 prey type occurred in a scat (e.g., chicken and 1 trial species), the percent of the scat composed of each prey type was estimated visually. Trace remains (< 5% of the scat) were excluded from estimates of diet. Dry mass of prey remains in scats were estimated by multiplying the dry mass of each scat by the percent of the scat composed of each prey type. All scats were analyzed by the same person (L.A.B.) to minimize variability caused by observer-related errors.

We determined dry matter digestibility for each feeding trial as (dry mass consumed – dry mass excreted) / dry mass consumed. Wet mass of food consumed was corrected to dry mass by multiplying wet mass consumed by percent dry mass of the prey type. Percent dry mass for small mammals, lagomorphs, and eastern grey squirrel were obtained from Litvaitis and Mautz (1980) and Powers et al. (1989). We estimated percent dry mass for white-tailed deer and juvenile feral hog by drying 10 samples of each species, composed of equal proportions of flesh, bone, and hide, at 60° C until mass loss ceased (Table 1). We used 1-way analysis of variance followed by Duncan's multiple range test (PROC GLM; SAS Inst. Inc. 1985) to test for significant differences between dry matter digestibilities.

Each feeding trial produced an observation of fresh mass of prey consumed per gram of remains (dry mass) in scats for the trial prey species. We regressed this ratio against live body mass of the trial prey to develop a predictive equation (PROC REG; SAS Inst. Inc. 1985). We examined Cook's distance, scatter plots of the original data, and scatter plots of studentized residuals against y to evaluate assumptions of the regression (Weisberg 1980). To evaluate the predictive value of the equation, we randomly chose 20 subsets consisting of 11 observations from the 15 feeding trial observations. We used regression analysis on each of the 20 subsets. From each of the subset regressions, we calculated predicted values for the 4 observations not included in the regression. We correlated 80 pairs of predicted and observed values (M. Conroy, pers. commun.) to examine how well the subset regression equations predicted independent observations.

A sample of bobcat scats was collected from Cumberland Island, Georgia, by searching roads, trails, and dune systems from October 1989 to August 1990. These scats were analyzed in the same way as the scats from the feeding trials. Frequency of occurrence was calculated as described above. Percent biomass consumed was estimated by multiplying the dry mass of remains of each type of prey by the correction factor for that species, and dividing that value by the sum of estimated biomass consumed for all prey types. For example, if we recorded a total of 150 g of deer remains in all the scats we analyzed, we would multiply that by 27.0 (our correction factor for deer) to produce an estimate of 4,050 g of deer consumed. We would then divide 4,050 g by the sum of the estimated grams consumed for all prey species to get percent biomass consumed for white-tailed deer. We calculated correction factors by using the average mass of the prey species (Table 1) in our regression equation. White-tailed deer were not included in the predictive equation, so the mean correction factor derived empirically from the feeding trials was used in estimating the amount of white-tailed deer consumed. Raccoons and birds were not included in our feeding trials, but were identified in the species from Cumberland Island. Because the average mass of raccoons (8.0 kg) was greater than any species used in developing the regression line, we used the correction factor for the largest species (deer) as the correction factor for raccoons. Birds were arbitrarily assigned a correction factor of 10.0 using our best judgment on the digestibility of birds relative to mammals. Johnson and Hansen (1979) reported that for coyotes the digestibility of mammals was "about" 80% and that of birds "about" 60%; therefore, we chose a lower correction factor for birds than the lowest one (15.6) for mammals. We used Spearman's rank correlation to test for a difference in rankings of prey species in the Cumberland Island scats between frequency of occurrence and percent relative biomass consumed (Corbett 1989). Significant correlation ($P < 0.05$) between ranks of prey species in bobcat diets using the 2 methods were assumed to indicate that there were no differences between the methods.

Results

Prey Consumption

Bobcats completely consumed all prey when the total mass of prey presented was < 1,500 g. For trials in which prey items were not consumed completely ($N = 11$), bobcats consumed 1,730 ± 324 g ($\bar{x} \pm$ SD). The greatest amounts consumed within 48 hours were 2,360 g of white-tailed deer and 2,100 g of juvenile feral hog. When fed portions of white-tailed deer, bobcats did not eat all of the bone, hide, and intestines. Only the skull was not eaten in the feeding trials involving a juvenile feral hog. Bobcats often did not consume hind legs, cecae, stomachs, and skulls of rabbits. The last scat collected that contained remains of a trial was collected an average of 5 ± 2 days after the prey item was offered.

Dry Matter Digestibilities

Dry matter digestibility increased with increasing prey size except for white-tailed deer (Table 1). Dry matter digestibility of white-tailed deer was less than that of both juvenile feral hog and domestic rabbit, although not significantly so. Digestibility of cotton mice and cotton rats was significantly less than feral hog

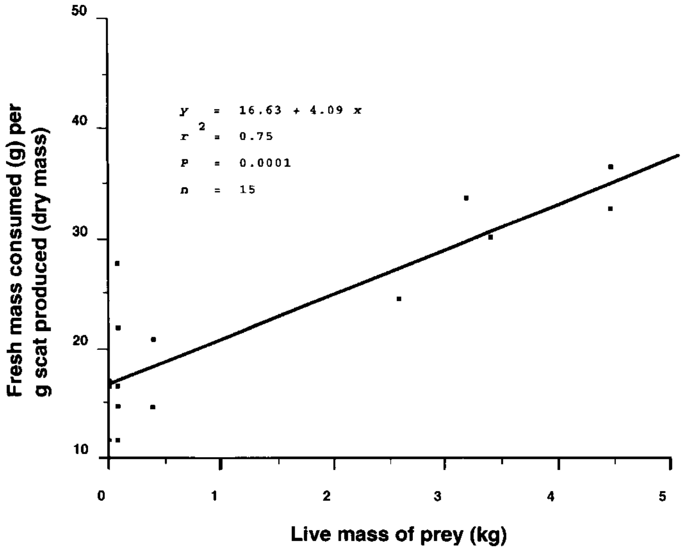

Figure 1. Relationship between fresh mass of prey consumed (g) per g scat produced (dry mass) (y) and the prey mass (x).

($P > 0.05$), and digestibility of cotton mice was significantly less than domestic rabbit ($P > 0.05$).

Regression Equation

We did not include white-tailed deer in the regression equation because empirical results from our feeding trials suggested that the number of grams

Table 2. Correction factors, frequency of occurrence, percent estimated biomass consumed, and rank of each prey species in the diet of bobcats by method, for prey species in 264 bobcat scats collected on Cumberland Island, Georgia, 1989–1990.

		Frequency of occurrence		% Biomass consumed	
Species	Correction factor	%	Rank	%	Rank
Marsh rabbit	21.3	40	1	44	1
Deer	27.0	35	2	37	2
Grey squirrel	17.2	10	4.5	5	3.5
Raccoon	27.0	5	7	5	3.5
Cotton rat	15.8	10	4.5	3	5
Bird	10.0	11	3	2	6.5
Feral hog	30.9	3	8	2	6.5
Cotton mouse	15.6	7	6	1	8

consumed (fresh mass) per gram of scat produced (dry mass) for white-tailed deer is similar to that for domestic rabbits and juvenile feral hogs (27.0 ± 5.9, 29.4 ± 4.7, and 34.5 ± 2.6, respectively) despite their much larger size. Therefore white-tailed deer probably violate the assumption that digestibility increases with prey size. Regression of biomass consumed per gram of scat produced on prey mass for all other feeding trials ($N = 15$) resulted in the linear relationship

$$y = 16.63 + 4.09x,\ r^2 = 0.75\ (P < 0.0001)$$

where y is the fresh mass of prey consumed (g) per gram of scat produced (dry weight) and x is live body weight of prey items (kg) (Fig. 1). There was no evidence of heterogeneity of variance in the data (Weisberg 1980). Therefore we used all data, untransformed, to develop the predictive equation. We assumed a normal distribution. Eighty independent observations were significantly correlated with their predicted values from 20 regressions of subsets of the bobcat feeding trials ($r^2 = 0.62$, $P < 0.0001$).

Comparison of methods

Comparisons of rankings between frequency of occurrence and percent relative biomass consumed were not significantly correlated ($P > 0.05$), indicating the two methods produced different rankings of species in the diet of bobcats for this sample (Table 2).

Discussion

We attempted to present prey to bobcats as whole animals with bones and hide intact. However such a presentation resulted in a lack of standardization of meal size. Meal size influences passage rate, and hence digestibility (Robbins 1983, B. Kelly, pers. commun.) For the larger prey items which bobcats fed selectively upon, we hypothesize that amounts eaten in our feeding trials approximate what would be eaten in the wild when bobcats eat to satiation. For smaller prey items which were entirely eaten, we cannot say how our meal sizes relate to a bobcat's average meal size in the wild, except to say meal size in the wild is probably extremely variable. In addition, we did not determine from the prey items the percent dry mass of prey consumed by bobcats. Our estimates of percent dry mass for animals which were not entirely eaten probably is higher than the actual dry mass of the prey consumed by bobcats, because bobcats probably selectively avoided hair and bone. Although the differences are probably very minor (± 5%) (P. J. Pekins, pers. commun.), a lower percent dry mass would result in a lower estimate or dry matter digestibility. Percent dry mass was not used in the calculation of correction factors or the regression line, and therefore errors in calculating percent dry mass did not affect those results.

The dry matter digestibility of prey fed to bobcats provides ambiguous support for the use of linear regressions based on prey size for bobcats. We had initially assumed that deer, because of their much larger body size and the ability of bobcats to feed selectively on them, would be more digestible and have a larger correction factor than the other prey items. This assumption was contradicted by our data, although all the other species tested demonstrated a clear size trend. Powers et al. (1989) recorded white-tailed deer as being 95.7% digestible to bobcats. However, they presented deer to bobcats as ground meat without skin, bones, head, gastrointestinal tracts, or lower portions of the legs. Litvaitis and Mautz (1980), working with coyotes, and Powers et al. (1989), working with bobcats, found that smaller mammals were more digestible to these carnivores than snowshoe hare (*Lepus canadensis*).

These results suggest that prey size may not be a good predictor of digestibility for some prey species. Other factors, such as type of hair, size of bones, age of prey item (degree of ossification), meal size, and the ability of carnivores to separate hair from more digestible portions, may be important in determining digestibility. More research in this area would be very valuable.

Contrary to Corbett's (1989) analysis of dingo (*Canis familiaris dingo*) scats, we did not find a correlation between rankings of prey species using frequency of occurrence and percent estimated biomass consumed in our sample of bobcat species. Use of the correction factors did not change the ranking of the major 2 prey items, which together composed 75%-80% of the diet. However, ranking of the lower-ranked prey items varied greatly between the methods. We concur with Corbett's (1989) conclusion that the frequency of occurrence method is suitable to survey prey use by carnivores, but an estimate of biomass consumed is required to determine the importance of different prey species, and to estimate the impact of carnivores on prey populations.

This study and Kelly (1991) suggest that use of empirically derived correction factors is justified, when possible. However, models that predict correction factors based on the assumption of prey digestibility increasing with prey size should be applied with caution; some prey species do not appear to meet the assumption of increasing digestibility with increasing size, at least for bobcats. In addition, researchers should be certain to duplicate the physical scat analysis techniques used in the original development of the model as these vary among models (Floyd et al. 1978, Kelly 1991).

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