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RELATING MARTEN SCAT CONTENTS TO PREY CONSUMED [1]

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A European ferret, *Mustela putorius furo*, was fed typical marten food items to discover the relationship between prey weight and number of scats produced per unit weight of prey. A correction factor was derived that was used in the analysis of pine marten, *Martes americana*, scats to produce a method capable of comparing foods on a "percent-by-prey-weight" basis. The results of this analysis are compared to traditional scat analysis methods and found to differ substantially. The differences were greatest when compared to analysis by "frequency-of-occurrence".

INTRODUCTION

Frequency of occurrence has been commonly used to relate carnivore scat contents to prey consumed, but the biases inherent in this method are well documented (Scott 1941, Latham 1951, Lockie 1959, Greenwood 1979, Korschgen 1980). Lockie (1959) and Gosczczynski (1974) tried to rectify this problem in the red fox, *Vulpes vulpes*, by deriving correction factors for converting fractional weights of scat contents to actual weights of prey. This was more accurate, but the authors did not account for the influence of prey size on the number of scats produced. Floyd, Mech, and Jordan (1978), experimenting with captive wolves, *Canis lupus*, discovered a strong negative correlation between the number of scats produced per kilogram of prey and the size of the prey item. This phenomenon was apparently due to the increasing proportion of indigestible material as prey size decreases.

During a study of pine marten ecology (Zielinski 1981, Spencer 1981) it became necessary to determine the seasonal diet. Because martens eat prey of many sizes, it is possible that the number of scats produced per unit weight of food eaten could be influenced by prey size. If the same relationship exists in marten scat production that Floyd et al. (1978) found in their analysis of wolf scats, ignoring it could seriously bias the results. For this reason I fed a captive male ferret (an animal which resembles a marten in size, weight and diet) a variety of typical marten foods to determine the number of scats produced per prey consumed. The feeding trials resulted in a procedure capable of estimating the original weight of prey remains discovered in marten scats. This information permitted the marten diet to be analyzed by "percent-by-prey-weight" which could be compared with traditional scat analysis methods. Work was conducted at the University of California, Sagehen Creek Field Station, Nevada Co., California (1950 m elevation).

METHODS

The feeding trials were run from April throuh July 1979. The animal was housed in a 1.5 x 1.5 x 0.75 m wire mesh cage in a small outbuilding where it was subject to normal photoperiod and temperature fluctuations. Water was provided *ad libitum*.

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Preliminary marten scat analyses and information from the literature were used to identify the principal marten prey items. Seven items were selected based on the diversity of sizes that they represented and their availability (Table 1). Unfortunately, the martens largest prey, the snowshoe hare, *Lepus americana*, was not available. Carcasses of each prey were weighed and offered to the ferret one at a time for 4 d. The orts (prey remains) were weighed daily and replaced until they had been fed upon completely or ignored by the ferret for 2 d. After the fourth day all orts were removed and the scat collection continued for an additional 24 h. The end of the fifth day of one trial usually became the beginning of the first day of the ensuing trial, allowing the ferret a minimum of 24 hours to become post-absorptive. This was probably sufficient because captive martens required no more than 19 h to pass the final scat from a meal (More 1978). Cessation of scat production also indicated a post-absorptive state.

TABLE 1. Pine Marten Prey Fed to Ferret and the Relationship of Prey Weight to Number of Scats Produced.

Prey item	*Mean prey[a] weight (g)*	*Number fed*	*Number scats per 100g prey*	*Grams of prey[b] per scat*
Peromyscus maniculatus	17.02	43	10.26	9.75
	17.70		8.73	11.45
Aves	21.90	26	9.80	10.20
	15.50		10.86	9.21
Microtus spp.	37.90	18[c]	8.97	11.15
	35.97		9.12	10.96
Eutamias spp.	50.40	15	7.24	13.81
	53.27		7.79	12.84
Glaucomys sabrinus	119.35	7	7.08	14.12
	126.70		6.05	15.38
Spermophilus lateralis	117.80	7	7.18	13.93
	140.60		6.49	15.41
Tamiasciurus douglasii	248.95	4	5.64	17.73
	189.80		6.73	14.88

[a] The first and second pair of numbers for each prey item refers to Day 1 plus Day 4 and Day 2 plus Day 3 trials respectively (see text).
[b] The mean weight of prey necessary to produce one scat.
[c] Three day trial.

Scats were collected as frequently as possible throughout the day and night to minimize trampling and to avoid confusion in separating scats deposited in aggregations. Although the first and last scats collected during a trial were less cohesive than those in between, they too were included in the analysis. Scats that resulted from meals fed on days 1 and 4 were analyzed separately from those on days 2 and 3. This was necessary because scat production did not usually begin until late in day 1, whereas scat production continued well after the final carcass was offered on day 4. Therefore, each 4 day trial resulted in two mean values (one for days 1 and 4 and one for days 2 and 3) for prey weight, number of scats per 100 g prey and the weight of prey necessary to produce one scat.

In an earlier study, 300 marten scats were analyzed according to three traditional methods: (i) frequency of occurrence (by number of items), (ii) volumetric percent of contents, and (iii) percent by weight of contents (Zielinski

1981). The present study provided a method of determining the number of scats produced per weight of prey consumed, which in turn were applied to marten scat data to provide a fourth method of analysis: "percent-by-prey-weight". This method was then compared to the traditional methods listed above. The marten scat analysis methods and a complete summary of the results are compiled by Zielinski, Spencer, and Barrett (1983).

RESULTS

The relationship of prey weight to scats produced is presented as number of scats produced per 100 g of prey and also by the weight of undigested prey that a scat represented (Table 1). The number of scats produced per 100 g of prey increased with decreasing prey size. Smaller prey items were eaten completely and produced more scats per unit weight than larger items. Weight of prey represented by each scat increased with increasing prey weight.

A strong positive correlation ($r^2 = 0.89$, $P < .005$) was discovered between number of scats produced by the ferret and the weight of prey consumed (Figure 1). Ultimately, the estimate of total prey weight consumed by martens was determined from the regression equation derived from ferret scat data. For example, the mean weight of 43 deer mice, *Peromyscus maniculatus,* fed to the ferret was 17.6 g (ln = 2.85), and the equation estimates that 9.9 g of prey of this weight will result in one scat. Thus, had 10 marten scats contained deer mouse exclusively, each representing 9.9 g of mouse eaten, then those 10 scats were produced by the consumption of approximately 99 g of mouse. The same value would result if deer mouse remains comprised fractional parts of more than 10 scats, but when totaled equaled 10 scats. Thus, 99 grams and its percent of total original weight of prey comprised the "percent-by-prey-weight" analysis. When the total weight for each prey species is divided by the mean prey weight, the number of individuals eaten can also be calculated (Table 2).

The four analysis techniques were compared using the information from scats collected from early spring to mid-summer, 1979 and 1980 (Figure 2). The histograms illustrate the four methods applied to nine prey items increasing in body size from left to right. This presentation includes only prey whose mean weights fall within the predictive limits of the regression, and is not intended to describe the marten diet but only to provide data for comparisons. Although flying squirrels, *Glaucomys sabrinus,* were not represented in the spring–summer marten scat data, they were included in the feeding trials to make the comparison of analysis techniques more robust.

Assuming "percent-by-prey-weight" is the most accurate interpretation of scat results, the three other techniques overestimate the importance of smaller items and underestimate the importance of larger items in the diet. Frequency of occurrence differed the greatest from percent-by-prey-weight. Occurrence as a percent of total number of items deviated from percent of original prey weight by 33% (when analyzed as percent of total number of scats the deviation was 38%). Percent weight and percent volume of scat differed from percent-by-prey-weight by 21 and 19%, respectively. The four techniques were most similar for prey of intermediate weight.

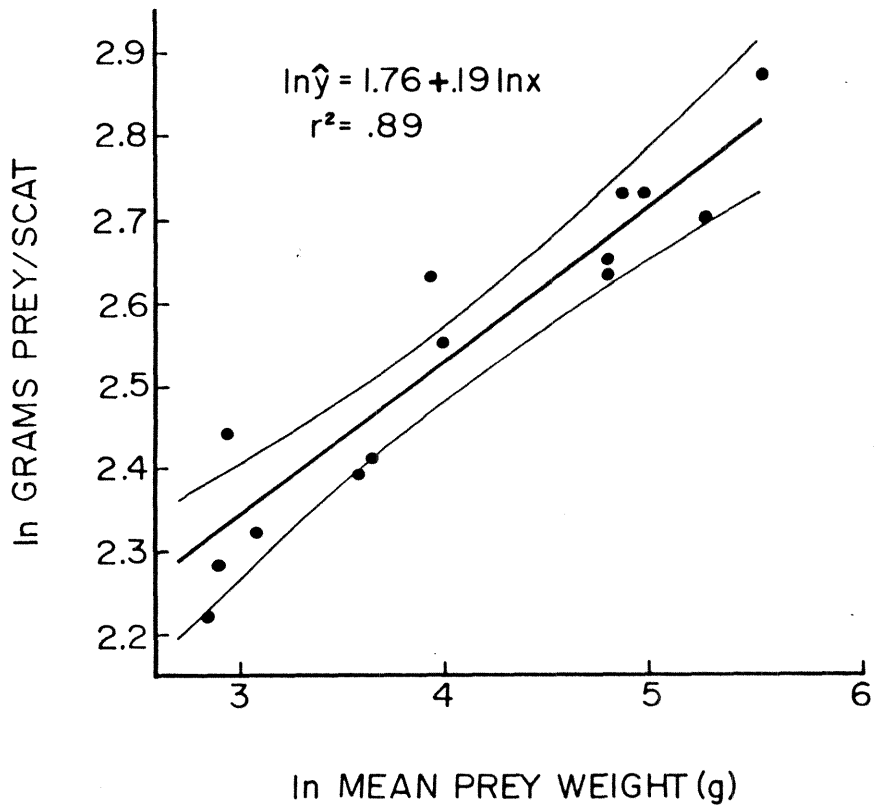

FIGURE 1. Relationship between prey weight and grams of prey required to produce one scat.

TABLE 2. Original Weights and Number of Individual Prey Represented by the Contents of Pine Marten Scats Deposited Between 25 April and 2 July 1979, 1980.

Prey item	*Mean wt.*[a] *(g)*	*Grams*[b] *prey/scat*	*Number*[c] *scats*	*Wt. of prey*[d] *eaten*	*Number*[e] *indiv. prey*
Sorex spp.	7.10	8.50	3.3	28.1	3.9
Peromyscus maniculatus	17.36	10.07	1.0	10.1	0.6
Aves	18.70	10.18	5.0	50.9	2.7
Microtus spp.	36.90	11.63	20.0	232.6	6.3
Eutamias spp.	51.83	12.43	6.2	77.1	1.5
Scapanus latimanus	68.70	13.07	3.1	40.5	0.6
Thomomys monticola	96.40	14.01	1.1	15.4	0.2
Spermophilus lateralis	129.20	14.73	10.6	156.1	1.2
Tamiasciurus douglasii	219.35	16.44	3.1	51.0	0.2
TOTALS			53.4	661.8	

[a] Average of carcasses fed during feeding trials or taken from museum specimens in Sagehen Creek field station collection.
[b] From ferret feeding trials.
[c] Composite number of marten scats which contained the item.
[d] Grams prey per scat multiplied by number of scats.

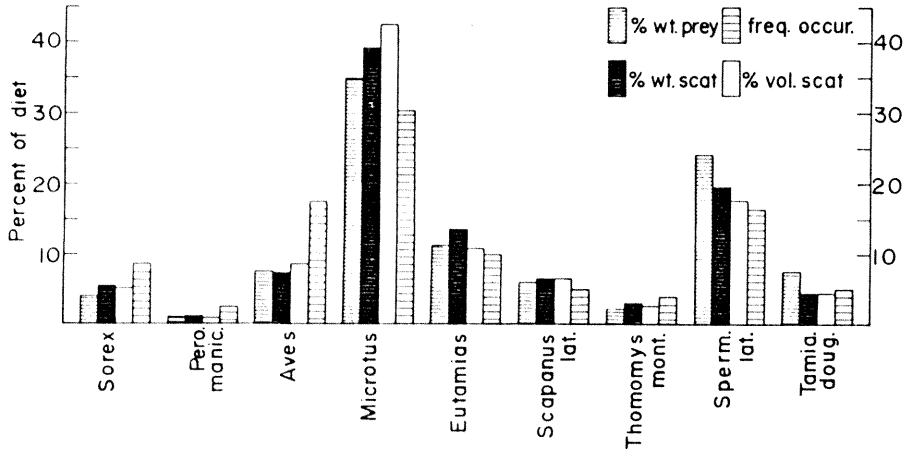

FIGURE 2. Comparison of four scat analysis techniques applied to selected prey discovered in marten scats deposited from 25 April–2 July 1979 and 1980.

Food items changed importance rankings when analyzed by different techniques (Table 3). Only three items changed ranked position when volume and weight are compared to percent-by-prey-weight. However, when frequency of occurrence is compared to percent-by-prey-weight, five items are ranked differently.

TABLE 3. Rank Order of Importance of Marten Prey as Determined by Different Analyses.

Prey	*Prey weight*	*Frequency of occurrence*	*Volume*	*Weight*
Microtus	1	1	1	1
S. lateralis	2	3	2	2
Eutamias	3	4	3	3
Aves	4	2	4	4
Tamiasciurus	5	7	7	7
Scapanus	6	6	5	5
Sorex	7	5	6	6
Thomomys	8	8	8	8
Peromyscus	9	9	9	9

DISCUSSION

Traditional scat analysis methods overestimated the importance of small prey and underestimated the importance of large prey. Two factors contributed to this result. The most significant influence was the fact that small prey have a higher ratio of undigestible to digestible matter in their bodies. Because the ratio of surface area to volume increases with decreasing body size (Kleiber 1947), the ratio of hair and feathers ingested per unit volume of body increases also. Johnson and Hansen (1979) found that the hair and skeleton of deer mice averaged 77.0% of dry weight, whereas 22.0% of the body weight of black-tailed jackrabbits, *Lepus californicus,* was recovered in scats. Secondly, small prey were entirely consumed whereas some hair, skin and the larger bones of large prey were often uneaten. Because less undigestible matter was consumed,

the larger prey produced fewer scats per 100 grams of their weight. This relationship would probably have been strengthened had very large prey, such as the snowshoe hare, been included in the feeding trials.

The variation among techniques was greatest at prey size extremes. Frequency of occurrence was a poor estimate of the undigested weight of small and large prey but approximated the weight of intermediate sized prey. This may be related to the size and similarity of prey at these weights. King (1980) found that when the weasel, *Mustela nivalis,* consumed prey larger than its stomach capacity, its stomach and scats rarely contained more than one prey type. For this reason, the usual disadvantages of frequency of occurrence analysis did not apply. The same exemption may hold true when martens or ferrets consume intermediate sized prey. Because *Eutamias* spp., *Thomomys monticola,* and *Scapanus latimanus* are of similar size and each probably exceeds the marten's stomach capacity, analysis by frequency of occurrence was a satisfactory estimate of their undigested weight. Frequency of occurence was also a reasonably close estimate of original vole, *Microtus* spp., weight despite their small size. Unlike other small mammals, vole remains were easily identified and regularly comprised the entire volume of the marten scat in which they were discovered. Because martens frequently hunt along meadow edges (Spencer 1981) where voles are common, several individuals may be eaten in succession, resulting in a homogenous series of scats comprised entirely of vole remains. This situation would result in a low ratio of frequency to volume much like that described for the intermediate sized prey above.

The unusually high frequency of occurrence of birds when compared to other methods is probably an artifact of the visibility of their remains and the amount of undigestible matter in their bodies. Were a mammal to be represented by only a few hairs, these would be much easier to overlook than feathers. Birds also contain a larger percent of undigestible matter than mammals of equal size (Johnson and Hansen 1979). Due to these characteristics, the avian component of the diet was extremely overestimated, appearing to exceed both *Eutamias* and *Tamiasciurus* when analyzed by frequency of occurrence. However, birds were ranked less than or equal to these mammals when analyzed by percent-by-prey-weight.

Lockie (1959) developed correction factors that he used to estimate the original weight of red fox (adult and cub) prey when multiplied by the weight of the remains in scats. He suggested that the correction factors for fox cubs might be suitable for martens as well. Although he came about the information differently, our procedures each resulted in an estimate of the original weight of prey and can therefore be compared. The only prey category for which a comparison is relevant however, is *Microtus,* since Lockie did not provide fox cub correction factors for any other mammalian category. Applying his correction factor to weights of marten scats containing vole remains resulted in an original weight estimate of 671.0 g. This was about three times the original weight estimate presented in the present analysis. Although this is by no means a critical test of his assumption, it does suggest that the fox cub scat correction factors may overestimate the original prey weights when applied to marten or ferret scat data.

Admittedly, inferences about marten feeding and digestion based on a captive ferret are tenuous. The ferret seemed less active than wild martens and activity

both stated that free-living fishers, *Martes pennanti,* were less active than captive ones. Although activity may accelerate the movement of food through the digestive tract, the rate of food passage is not important provided the digestibility is not affected. Documentation of this relationship is lacking, however.

In summary, although all traditional techniques were found to overestimate the importance of small prey and underestimate large prey, volumetric estimates of prey remains came closest to estimating the weight of the prey included in the trials. For this reason, and because relative volume of scat contents is easier to estimate visually than relative weight, volumetric measures are recommended for the analysis of marten scat contents.

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