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AN ASSESSMENT OF QUANTITY OF PREY CONSUMED BY WOLVES THROUGH ANALYSIS OF SCATS

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by

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A Thesis

Submitted in Partial Fulfillment of the

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ABSTRACT

A regression equation to estimate proportion of weights of different prey species in field collected wolf (Canis lupus) scats was developed by feeding fifteen carcasses of known weight to four to five captive wolves, and collecting and weighing scats produced. From these measurements, prey weight per collectible scat was calculated for each trial and was plotted against total prey weight (kg).

Separate regression lines of summer and winter prey animals were compared; the position of the curve for winter prey animals was higher than that for the summer prey animals, indicating that more weight in scats was produced by wolves feeding on winter prey of equivalent weight.

The overall regression line from my study was lower than that of Floyd et al. (1978), possibly the result of including five adult deer (Odocoileus virginianus) and one moose calf (Alces alces) greater than 40.0 kg. Variations in my study, as described by the coefficient of determination (r^2) values, was higher than in the Floyd study.

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INTRODUCTION

Knowledge of food habits is important in understanding the ecological relationships of any species within a natural community. Feeding habits of the wolf (*Canis lupus*) have been studied in Europe and North America, but quantitative data on energy values and prey items are often lacking. Field techniques have been developed to assess the wolf's food habits whereby droppings or "scats" are analyzed to determine species content via identification of bones and hair. Techniques are likewise available for determining age class of prey animals.

Scats can be used to study energy utilization in wolf populations. By counting and weighing scats, the daily caloric output of a pack can be estimated; from this, biologists can estimate the quantity of food metabolized by the pack as well as appropriate food intake. Energy derived from assimilated food is available for work, growth, and reproduction. The determination of assimilation efficiency (the quantity of food assimilated or metabolized divided by the quantity of food ingested) is useful in management programs when calculating the quantity of food intake per wolf pack per year required to sustain each member.

Until recently, proportions of prey animals consumed by carnivores over a period of time have been estimated by using the percentage of occurrence method; i.e., the percentage of the total number of scats in which a prey item occurs (Lockie, 1959).

Scats are usually collected in the field, separated according to prey species, and counted. The number of scats containing each prey item is divided by the total number of scats produced. This gives percentage of occurrence of each prey item. Such results have limited use, however, in estimating the weights and actual numbers of different prey items consumed because of differing proportions of undigested materials in different prey items. Small animals are generally composed of a greater proportion of undigestible material such as hair and bones than larger animals (Mech 1966, 1970). This is explained by the fact that small prey animals, including snowshoe hare (Lepus americanus) and beaver (Castor canadensis) have a larger surface area to volume ratio than larger prey animals. Since scats are largely composed of hair, small animals have a larger proportion of hair per volume of digestible body tissues than larger animals. Pimlott (1967) disagreed with Mech's hypothesis that small prey animals may be over represented; he believed that the proportion of remains in scats represents the actual proportion in the kill, though this was not tested in his Ontario study (Pimlott et al. 1969). Voight et al. (1976) believed that the percentage of occurrence method produced minimal bias in their study of wolves and prey in Ontario since similarly sized prey species (beaver and deer fawns) made up a large proportion of prey items.

Mech (1970) listed other factors which may influence the proportion of adult and young prey animals represented in scats compared to the proportion actually killed: (1) larger chunks of hide are more commonly left by kills of adult deer, moose (Alces, alces), or caribou (Rangifer caribou) during winter, whereas most or all of the hide of summer moose calf, caribou calf, or deer fawn kills is consumed; this tends to further reduce the proportion of undigested remains of large animals in scats; (2) more flesh and less hair is taken from an adult moose or deer kill than is taken from a deer fawn or moose calf kill, with a similar effect; and (3) wolves tend to stay near an adult kill during the summer while finishing it, and scats are concentrated in one place, whereas during the winter and spring, wolves finish a calf or fawn kill quickly and continue traveling leaving scats on trails where they may be more likely to be collected, assuming collecting is done primarily along trails such as has been done in some studies. This problem is one of sampling design and is beyond the scope of this study.

To account for the possible error of over representation of small prey items in scats, Lockie (1959) worked out a correction factor. In a controlled study, three adult red foxes (Vulpes vulpes) were fed various prey items [(voles (Microtus agrestis) and mice (Apodemus sylvaticus), rabbit (Oryctolagus cuniculus), rat (Rattus rattus) and bird (Columba spp.)] of known weight. The weight of each prey item was divided by the weight of undigested material (scats) to obtain a correction factor for each prey type, but no general equation was developed.

Floyd et al. (1978) developed a method to determine the percentage of individual prey species and to estimate the number of individuals of each prey species represented in field collected wolf scats. So that actual weights of prey consumed could be determined for the weight and number of wolf scats collected, Floyd and his co-workers developed a linear regression equation using prey weight as the independent variable and prey weight per collectible scat as the dependent variable. The study was conducted by feeding captive wolves prey animals of known weight, and scats were collected until scat production ceased. Once prey weight per collectible scat was calculated for each prey time, it was plotted against the weight of the prey item. A line was then estimated by regression analysis:

$$y = 0.38 + 0.02x$$

where (x) represents prey weight, 0.02 is the value for slope, 0.38 is the y-intercept, and (y) represents kg prey per collectible scat. The regression line and an equation developed in the study of Floyd et al. (1978) can be used to quantitatively interpret food habits of wolves or other large carnivores, from scats collected in the wild (see Figure 9, page 16 for example). The equation:

$$\text{Prey Weight Consumed} = \underset{\text{Scats}}{\text{Number of Collectible}} \times \underset{\text{Scat}}{\text{Prey Weight per Collectible}}$$

must first be solved. The number of collectible scats per prey item fed to the wolves is obtained by separating scats consisting of each prey type (by inspecting hair, bones and teeth) and counting the number of scats representing each prey species. Mech (1966) noted that in general, each wolf scat contains one species because the type of prey is so large. Prey weight per collectible scat is determined by solving for (y) in the regression equation developed from the controlled study. The (x) variable represents the estimated average weight of each prey species.

The proportion of each prey type consumed by wolves can be calculated by the total weight of all prey animals consumed. The average number of individuals of each prey type can be calculated by dividing the prey weight consumed (for each species) by the estimated live weight of prey. This recently refined method of scat analysis produces more accurate results than the percent of occurrence method since scat weight and frequency are considered when estimating numbers and the proportion of prey items utilized by carnivores (for a detailed example see pp. 22-23).

Floyd et al. (1978) did not take into account two factors which may affect the accuracy of their technique. First, there may be seasonal differences in the weight of the prey pelage, and therefore differences in the amount of undigestible material present in scats in summer and winter. Secondly, only a single adult white-tailed deer was used in their study so that no range of variation of digestibility among larger prey animals was described. Further information is necessary to assist field biologists in making more accurate determination of numbers of prey animals consumed through scat analysis.

The objectives of my research were to:

(1) improve the accuracy in determining the number of prey animals consumed using wolf scats.

(2) determine assimilation efficiency of a captive wolf pack.

METHODS AND MATERIALS

Enclosure

The wolves were maintained in a 1.35 ha enclosure located in a densely wooded area in Ishpeming Township, Michigan. Vegetation within the enclosure consisted mostly of balsam fir (*Abies balsamea*), eastern hemlock (*Tsuga canadensis*), white birch (*Betula papyrifera*), and white pine (*Pinus strobus*).

Feeding trials were conducted within a 0.10 ha fenced off portion of the enclosure (Figure 1). A den approximately 7 meters long was constructed by the pack within the feeding area.

Summer 1981 temperatures (June - September) ranged from 15-32^{o}C during the day and from 10-21^{o}C at night. Winter 1981-82 temperatures (December - March) ranged from a high of 0^{o}C to a low of -21^{o}C. Snowfall ranged from a high of 209.8 cm in December to a low of 24.4 cm in March (U. S. Weather Bureau, 1982).

History of the Captive Wolves

The captive wolf pack is comprised of two four-year-old wolves, one male and one female, two two-year-old females and one male pup (Figures 2, 3, 4, and 5). The four-year-olds were taken from two separate captive wolf packs in Minnesota when they were pups. The two-year-olds were born in April of 1978 to the adults. A litter of four pups was born 19 April, 1981 to the adult male and one of his daughters. Three members of the litter were removed, and one male pup was kept.

Figure 1. Partial view of the feeding trial enclosure (0.10 ha).

Figure 2. Four-year-old male timber wolf.

Figure 3. Four-year-old male (grey) and female (black) timber wolves.

Figure 4. Four-year-old male and female timber wolves and their two-year-old daughters (in resting position).

Figure 5. Six-month-old male timber wolf pup feeding on deer remains.

Feeding Methods

Each feeding trial was conducted using either a single adult or fawn white-tailed deer carcass, four to six adult snowshoe hare carcasses, three beaver carcasses, or one moose calf carcass (Figures 6 and 7). Deer carcasses (road kills or poached animals) were obtained from the Michigan Department of Natural Resources in Iron County. Hare were donated by local hunters, and beaver, trapped during the legal trapping season, were donated to the study.

At the beginning of each trial, four to five wolves were impounded in the 0.10 ha enclosure and were fasted for 48 hours. For each trial, a frozen carcass was weighed (wet weight) on a Fairbanks standard medical scale and then thawed for 24-48 hours, depending upon its size. Before each carcass was fed to the wolves, old scats and bones were removed from the entire feeding enclosure. The carcass was placed in the enclosure and left until the wolves stopped eating; small prey carcass were consumed in one to two days and large prey carcasses were consumed in three to six days. Scats were collected twice daily, individually bagged in plastic, and stored in a freezer. Loose scats, dark watery substances with no structural conformation, were considered uncollectible, and were discarded. Such scats found in the field would quickly be dissolved by rain and snow. Based on observation, approximately 30% of the scats found in each trial were considered uncollectible. Floyd et al. (1978) found that 36% of the scats were uncollectible per feeding trial. At the end of each trial, usually 4 to 6 days, the enclosure was thoroughly searched for carcass remains - hide, hair, and rumen.

Individual scats were weighed to the nearest 0.1 gram on a Mettler scale (model # PN2210). Hair and small bone fragments remaining in the

Figure 6. Moose calf carcass (183.59 kg) in feeding trial enclosure.

Figure 7. Wolves consuming the moose calf carcass.

enclosure were also weighed on the Mettler scale. The Fairbanks scale was used to weigh larger bone fragments and deer or moose stomach contents.

The total weight (kg) of scats and number of scats was calculated for each trial. The percentage of prey weight which was defecated was determined by dividing the total weight of collectible scats by the total prey weight, i.e., wet weight (Appendix A, B, C). The number of collectible scats per total wet weight of prey eaten was also calculated. Total wet weight (kg) per number of collectible scats, calculated from each trial, was plotted against prey weight (total wet weight) and a linear regression analysis was conducted utilizing these two parameters.

Method of Determining Assimilation Efficiency of a Captive Wolf Pack

The equation for assimilation efficiency (Ricklefs 1973) can be expressed as follows:

Assimilation Efficiency (A.E.) = Assimilation/Ingestion

$$\text{A.E.} = \frac{(\text{kcal/gram estimated* dry wt. ingested}) - (\text{kcal/gram dry wt. defecated})}{\text{kcal/gram estimated* dry wt. ingested}}$$

*Percent dry weight of prey obtained from Litvaitis and Mautz (1980).

An attempt was made to determine assimilation efficiency by drying and weighing scats and deriving caloric values with a bomb calorimeter (Appendix D, E, F). Dry weights of collectible scats are given in Appendix E. Due to the inaccuracy of the equipment used, no reliable caloric values for scats could be derived. Thus, no assimilation values were calculated.

RESULTS

An inverse relationship was found between the weight of prey eaten by the wolves and the number of collectible scats per kg of prey (Figure 8). The smallest prey animals, a snowshoe hare, weighed 1.20 kg; on the average 5.42 scats were produced per kg hare. The largest prey animal consumed was a 183.59 kg moose calf, and 0.48 scats per kg prey were produced by the wolves.

The relationship between prey weight and prey weight per collectible scat for all trials conducted, is graphed in Figure 9. The line produced by Floyd et al. (1978) is also shown. Both regression lines were calculated using the least squares method:

$$y = b + mx$$

where the y-intercept (b) = 0.26525
slope (m) = 0.0110
x = total prey weight (kg)
y = prey weight per collectible scat

The correlation coefficient ($r = 0.858$) revealed a positive correlation ($p \leq 0.01$) between prey weight per collectible scat and prey weight. The coefficient of determination ($r^2 = 0.735$) indicates that about 74% of the variation in weight of prey per collectible scat is attributed to weight of the prey they come from, i.e., 74% of the variability among prey weight values can be accounted for by variations among prey weight per collectible scat values (and vice versa). The remaining 26% is unaccounted for, but probably relates to such factors as differences in the proportion of digestible material in prey animals and the possible loss of scats in the snow during winter. Regression lines were constructed separately for winter and summer prey items (Figure 10). The line for winter showed a significant positive correlation ($r = 0.890$; $p < 0.05$). The correlation for summer prey items was not significant ($r = 0.559$; $p > 0.05$).

In order to determine whether a significant difference exists between the study of Floyd et al. (1978) and the present study, 95% confidence belts (Sokol and Rohlf, 1969) were constructed for each regression line (Figure 11). There is a slight overlap of the two regression belts at the lower end of the weight scale. A t-test was used to test the difference between slopes obtained in the two studies (Sokol and Rohlf, 1969). The t value (2.043; at 20 df; $t(0.05) = 2.086$) indicates a low probability that the slopes are the same.

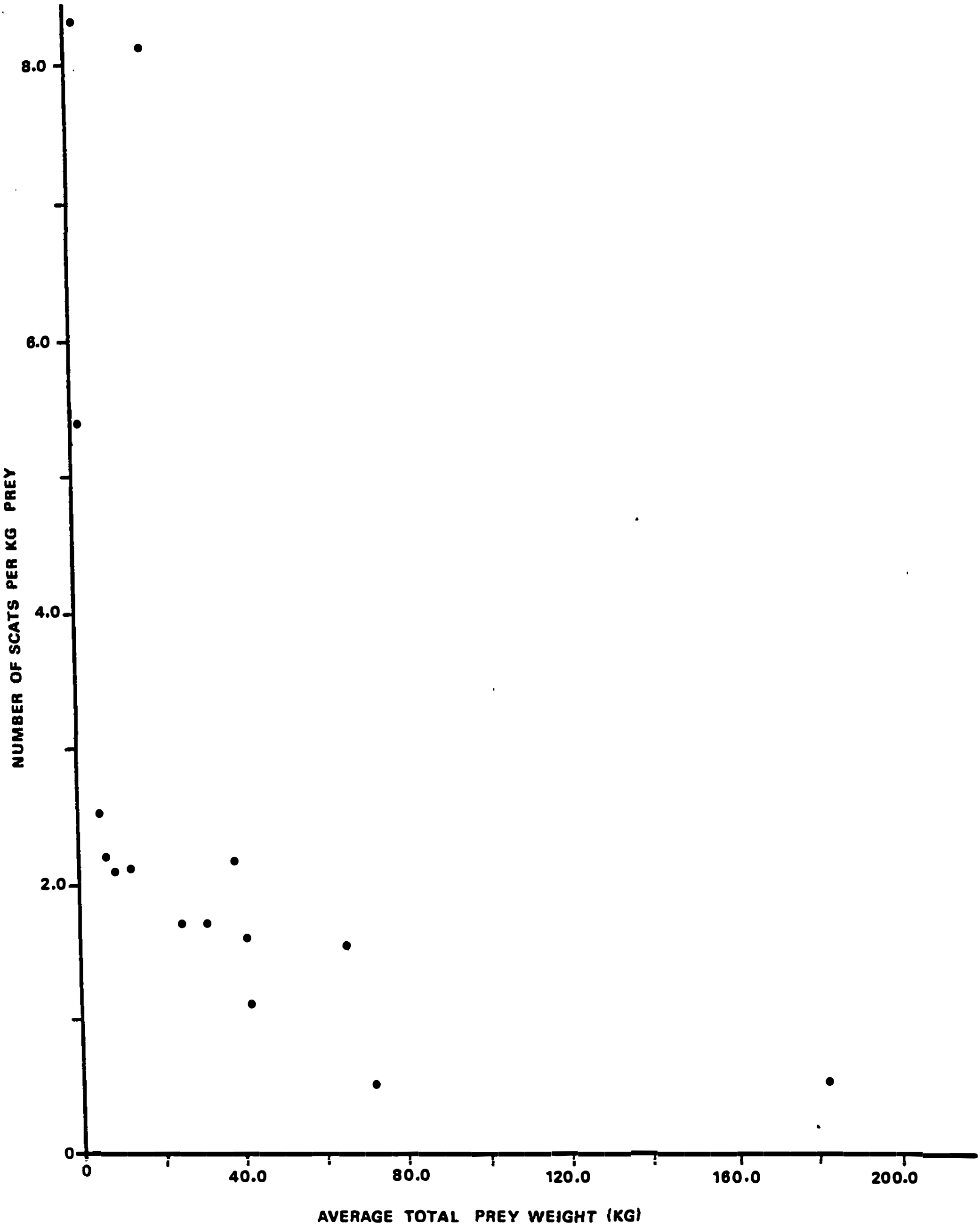

Figure 8. Relationship between the number of scats per kg prey (y) and average total prey weight (x) of a captive wolf pack.

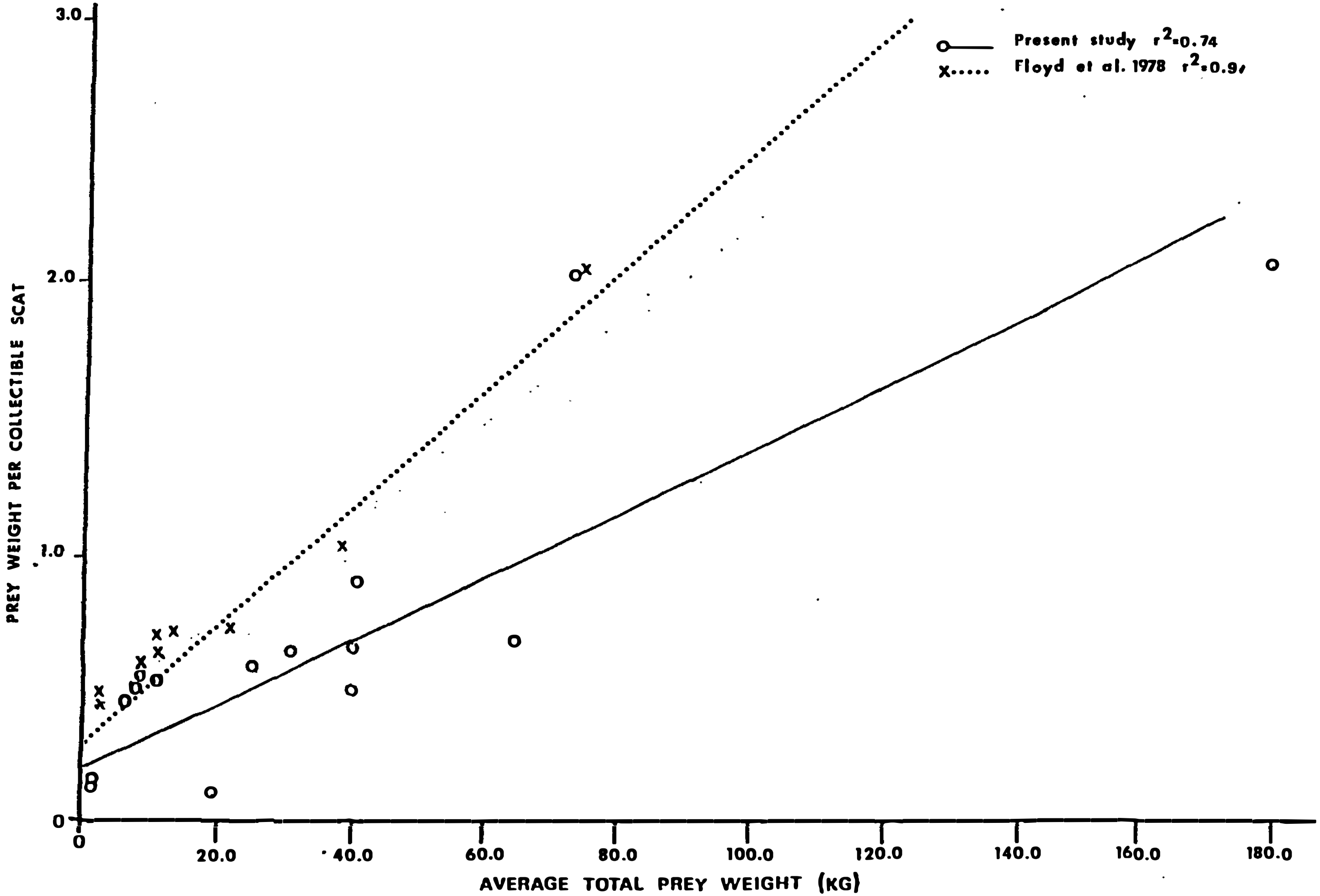

Figure 9. Relationship between the weight of prey (kg) per collectible scat (y) and the average total prey weight (x) fed to a captive wolf pack.

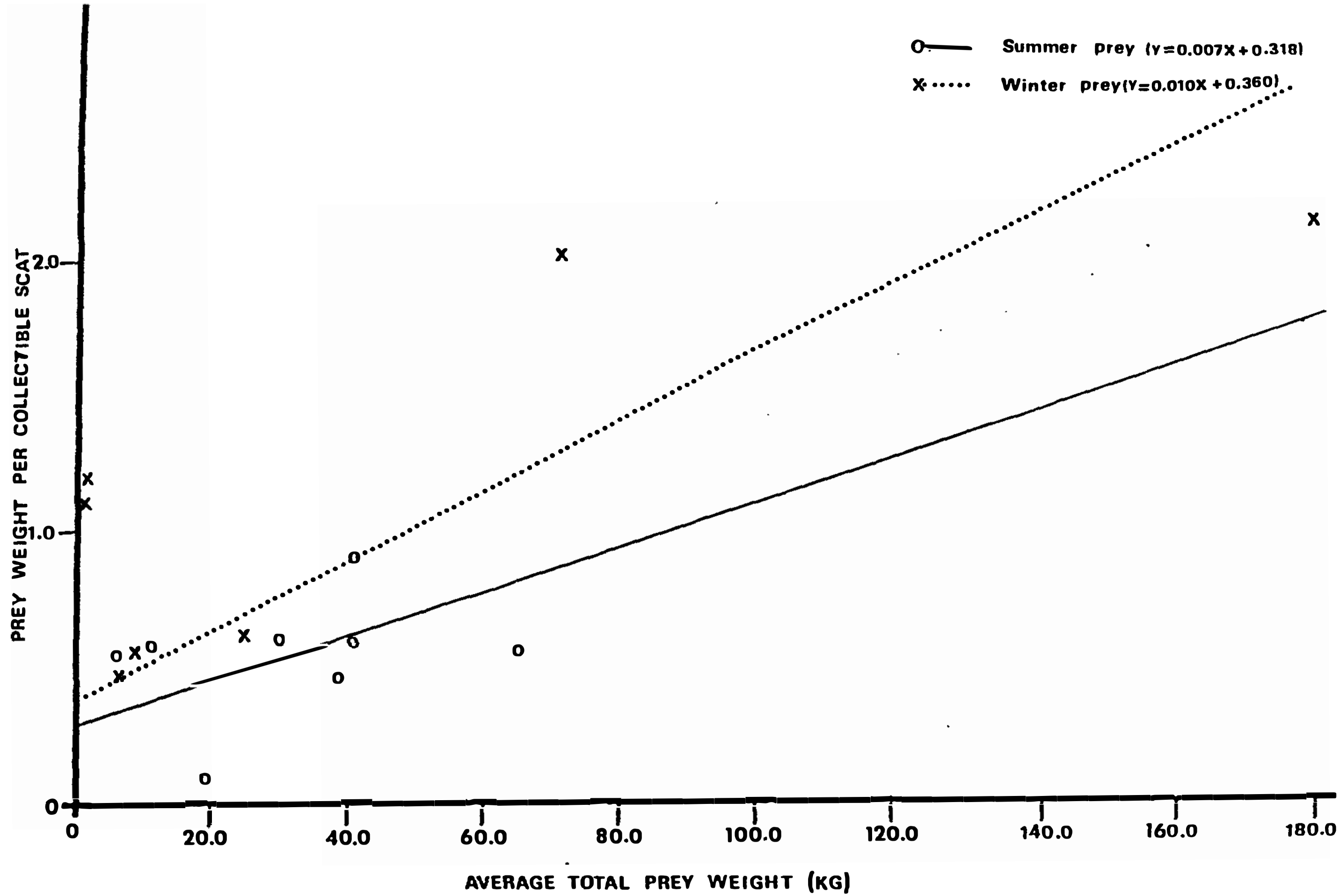

Figure 10. Relationship between the weight of prey (kg) per collectible scat (y) and the average total prey weight (x) of summer and winter prey fed to a captive wolf pack.

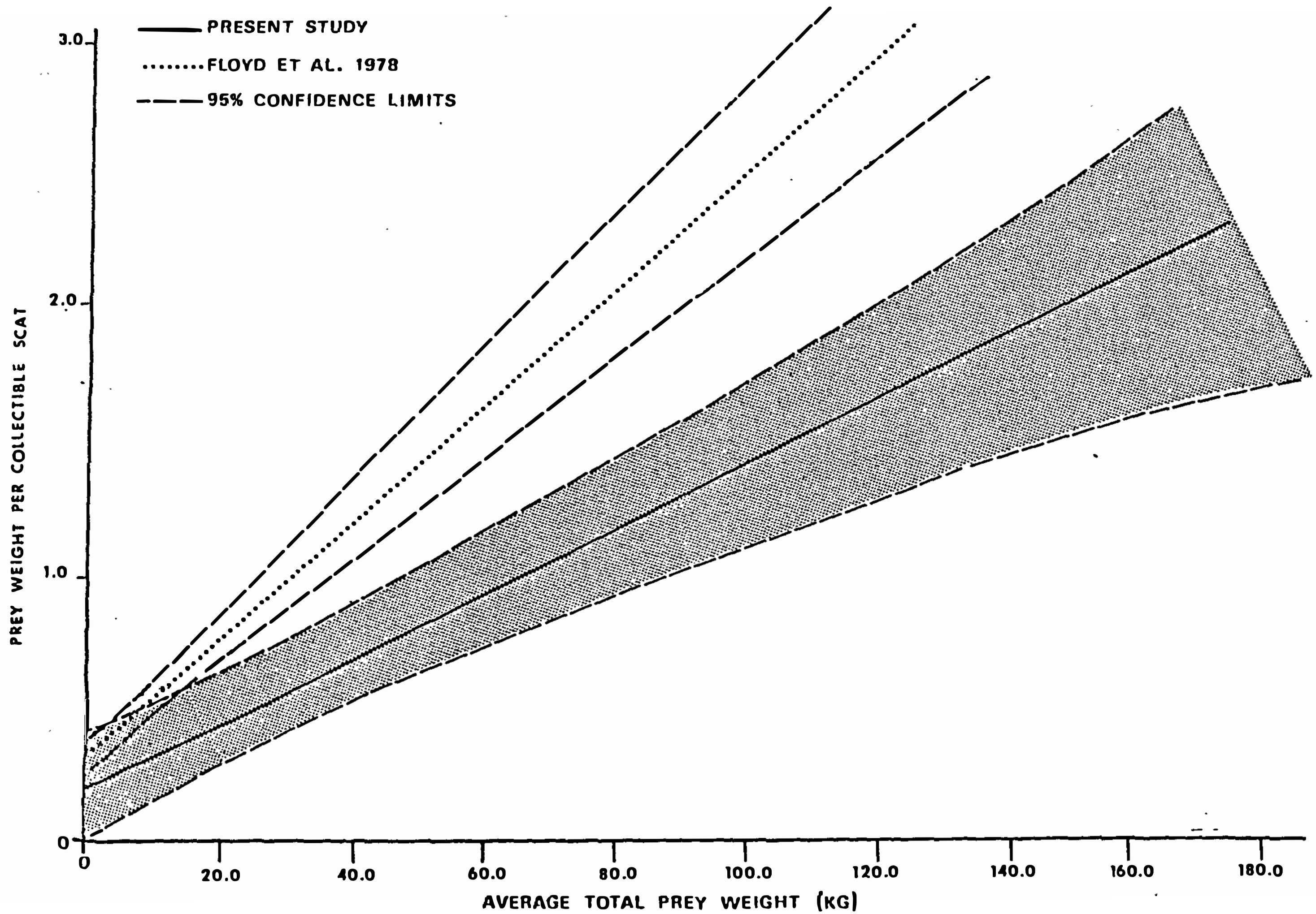

Figure 11. Relationship between the weight of prey (kg) per collectible scat (y) and the average total prey weight (x) with 95% confidence belts for the regression line of two studies.

DISCUSSION

An inverse relationship existed between the number of collectible scats per kg prey and total weight of prey eaten. This relationship is based on the premise that the proportion of undigestible material is greater in small animals than in large animals. This observation agrees with Mech's (1966) hypothesis stating that small prey animals eaten are over represented in scats.

Separate regression lines of summer and winter prey animals were compared to see if the relationship between prey weight and prey weight per collectible scat changed with season. The position of the curve for winter prey animals (slope = 0.0111) was higher than that for summer prey animals (slope = 0.0065), although the correlation coefficient of the latter was not significant. In general, however, this indicates that more weight in scats was produced by wolves feeding on winter prey than summer prey of equivalent average weight of prey. The relationship agrees with the hypothesis that undigestible material of prey animals tends to be greater in winter than in summer. This is probably because of the thicker winter pelage, and consequent higher proportion of hair, which is undigestbile and passes through the scats.

Differences exist between the results of this study and that of Floyd et al. (1978). Coefficient of determination values for the regression line are different in both studies. My research produced a smaller r^2 value (0.735) than that of the Floyd study ($r^2 = 0.97$). The smaller r^2 value indicates more variation about the regression line.

Several factors may have contributed to the smaller value (0.74) in the present study. First, the Floyd et al. (1978) study was conducted in an enclosure with cement floors, therefore, scat collection was more complete. The present study was conducted in an enclosure with natural ground, thus making complete scat collection more difficult, although a concerted effort was made to locate all scats produced. Carcass remains were sometimes difficult to collect in the present study enclosure because the wolves were able to cache the meat in holes and in their den. The exact extent of this problem could not be determined, but caching was probably responsible for greater variation of scats per prey weight in my study. Occasionally, a pause was noted in scat production after a carcass was removed from the pen, followed by further scats, suggesting that the wolves were feeding on cached material. Secondly, scat collection was also less accurate in the present study during the winter season when snowfall was heavy and continuous. Although scats were collected twice daily during this time, a few scats were buried and not collected. Third, more trials were conducted with larger animals (adult deer and one moose) in the present study than in the previous study, and there may be more variation in digestible material in larger animals. Though there may be no real difference between the slopes of each study, the probability that they were similar was low.

Social hierarchy within the wolf pack may play a role in causing variation in scat production in the field as well as in captivity, i.e., the weight of scats produced could vary among individual wolves due to hierarchial differences. In general, dominant pack members may consume a larger quantity of the most desirable pieces of meat (muscle), whereas, the subordinate individuals may feed on remaining carcass parts such as bone, hide, and hair (Mech, 1970). Thus, dominant wolves will produce fewer scats than their subordinates, since the majority of their diet consists of the more digestible parts.

Seasonal availability may also play a role in scat production. During some winters when prey is most vulnerable, wolves may gorge themselves on choice parts of a carcass and then abandon it (Mech, 1970). Mech observed this behavior during a winter of a high snowfall when deer were immobile. This behavior has also been observed by Pulliainen (as cited in Mech, 1970) when wolves have increased accessibility to domestic animals. This type of feeding behavior in the wild may parallel the feeding behavior found in captive wolves. Since the captive wolves are being supplied with food on a regular basis, they may select only the most desirable carcass parts and leave the rest. This would undoubtedly reduce the number of scats produced per total prey weight.

Finally, the size of the prey animal may determine the quantity of scats produced. During the present study, carcass remains (limbs, stomach contents, and jaws) were collected at the end of prey trials using large animals including an adult deer and a moose calf. However, no carcass remains were left by the wolves when small prey such as snowshoe hare and beaver were fed to them. Thus, the tendency to leave parts of large prey animals uneaten would also reduce the number of scats produced.

The technique of Floyd et al. (1978) is more accurate than the commonly used percentage of occurrence method to describe and compare percentages of individual prey types consumed by a wolf pack. Error is more likely to occur with the percentage of occurrence method since scats containing small prey animals and relatively more undigestible material, are counted equally with those containing large prey animals, thereby over representing the relative contribution of small animals to the diet (Mech, 1970).

The following hypothetical example illustrates how the technique of

Floyd et al. (1978) and my study can be used to estimate the proportions and the average weights of individual prey species consumed by wolves in the wild. For example, suppose 300 wolf scats are collected around the denning and rendezvous sites of a wolf pack during spring and summer seasons. The scats are separated by the researcher according to hair and bone type found in each trial. Out of the 300 scats found, let us say, 50 scats consisted of snowshoe hare, 75 scats consisted of deer fawn, and 175 scats consisted of adult deer (a single scat represents one prey species, as remains of prey species are seldom mixed in wolf scats). In order to calculate the total weight of prey eaten by the pack, the following equation would be used for each prey species:

$$\text{Weight of Prey Eaten} = \begin{matrix}\text{No. of Scats of}\\ \text{Each Prey Type}\end{matrix} \quad \text{X} \quad \begin{matrix}\text{Prey Weight (kg)}\\ \text{Per Collectible Scat}\end{matrix}$$

Prey Weight (kg) per collectible scat is obtained from the linear regression (Figure 8). The average prey weight (x) of one hare is 1.31 kg. Prey weight per collectible scat (y) is obtained from the regression:

$y = b + mx$.

Kg of hare eaten = (50 hare scats) x (0.27 kg hare/hare scats)[a]
Kg of hare eaten = 13.5

[a]Based upon average weight of hare used in the present study = 1.31 kg

Kg of deer fawn eaten = (75 fawn scats) x (0.47 kg/scat)[b]
Kg of deer fawn eaten = 35.3

[b]Based upon average weight of deer fawn used in the present study = 18.4 kg

Kg of adult deer eaten = (175 deer scats) x (0.84 kg/scat)[c]
Kg of adult deer eaten = 147.0

[c]Based upon average weight of adult deer used in the present study = 51.9 kg

The total weight of prey eaten can now be calculated by summing the weight of each prey species eaten:

Total kg of prey eaten = 195.8

The percentage of individual prey items consumed by the wolf pack is calculated by the following method:

13.5 kg hare/195.8 kg total prey eaten	=	7% hare
35.3 kg fawn/195.8 kg total prey eaten	=	18% fawn
147.0 kg adult deer/195.8 kg total prey eaten	=	75% adult deer

Finally, the average number of individual prey items consumed by wolves is calculated in the following way:

13.5 kg hare/1.31 kg (average weight of adult hare)	=	10.3 hare
35.3 kg fawn/18.4 kg (average weight of fawn)	=	1.9 fawn
147.0 kg adult deer/51.9 kg (average weight of adult deer)	=	2.8 adult deer

Applying the hypothetical sample data used to compare the method developed by Floyd et al. (1978), with results based upon percentage of occurrence, yields percentage values in the proportion of individual prey items as follows:

<u>Hypothetical data</u>

50 snowshoe hare scats
75 deer fawn scats
175 adult deer scats

300 total number of scats

Proportion of individual prey items consumed by wolves:

Percentage of Occurrence	*Floyd et al. (1978) Method
17% snowshoe hare	7% snowshoe hare
25% deer fawn	18% deer fawn
58% adult deer	75% adult deer
100% Total	100% Total

*(calculations in hypothetical example)

When the differences in digestibility are not taken into consideration, proportion of large prey animals tends to become under represented and smaller prey become over represented as illustrated above.

Proportion of individual prey items consumed by wolves was also calculated using the regression equation produced in the study of Floyd et al. (1978). A 1.0% difference resulted when comparing these values with the percentage values obtained using the present regression equation:

	Floyd et al. (1978) Equation ($Y = 0.021X + 0.342$)	Present Study Equation ($Y = 0.011X + 0.265$)
Hare	6%	7%
Deer Fawn	17%	16%
Adult Deer	75%	75%
Total	100%	100%

The previous example used snowshoe hare, deer fawns, and adult deer. If only larger prey animals including deer fawns, adult deer, and a moose calf are considered, the following results are obtained:

	Floyd et al. (1978) Equation	Present Study Equation
Moose Calf	63%	63%
Adult Deer	24%	23%
Deer Fawn	13%	14%
Total	100%	100%

This small (1.0% difference suggests that it makes little difference which equations is used in comparing proportions of different prey animals eaten. The reason for this is that the proportions depend only upon the slope of the regression line, and not upon the y-intercept. The slope of the Floyd et al. (1978) equation was 0.021 while the slope obtained in my study was 0.011. The shallower slope obtained in my study could be attributed to the use of more large animals, particularly a calf moose, which brought the curve downward. Because of this, it might be more desirable to use my equation when considering large prey animals.

With the use of these equations, biologists may gain a more complete understanding of relationships between predators and their prey. Modifications made in this study, over those presented by Floyd et al. (1978) include: the addition of several large prey items, i.e., five adult deer and one moose calf carcass so that a range of variation of digestibility among large prey items could be described, and the consideration of seasonal differences in the amount of undigestible material present in scats in summer and winter. Additional testing is recommended, however, with closer controls on scat collection using a variety of sizes of prey animals.

The determination of assimilation energy values is also useful in management programs when calculating the quantity of food intake per wolf pack per year required to sustain each member. Attempts to determine assimilation efficiency were frustrated however, by the failure of the bomb calorimeter to handle heterogeneous material, i.e., scats. Further work needs to be done, using an adiabatic calorimeter, to assess energy utilization by carnivores.

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APPENDIX A

Calculations made from scat analysis.

Prey/Trail	Prey Weight (kg) Total	Prey Weight (kg) Eaten	Fresh Weight (kg) Collectible	% Prey Weight	% Prey Eaten	No. of Collectible Scats Per Kg. Prey	Kg. Prey Per Collectible Scats	No. of Scats
1) Fawn deer	6.35	6.35	1.23	19.37	19.37	2.52	0.40	16.0
2) Fawn deer	10.37	10.37	1.21	11.67	11.67	2.12	0.47	22.0
3) Fawn deer	18.96	18.96	1.54	8.10	8.10	8.07	0.12	153.0
4) Fawn deer	25.00	19.55	3.53	14.12	18.10	1.84	0.54	46.0
5) Yearling deer	31.30	31.00	6.16	19.70	19.90	1.69	0.59	53.0
6) Adult deer	39.55	35.37	9.88	24.98	27.93	2.17	0.46	86.0
7) Adult deer	40.27	40.27	7.72	7.72	19.17	1.64	0.61	66.0
8) Adult deer	41.00	39.86	6.87	16.76	17.24	1.10	0.91	45.0
9) Adult deer	65.60	57.48	10.52	16.06	18.30	1.56	0.64	102.0
10) Adult deer	74.09	29.82	3.47	4.70	11.64	0.50	2.00	37.0
11) Moose calf	183.59	106.49	11.43	6.23	10.73	0.48	2.09	88.0
12) Average Hare	1.41	1.41	0.96	68.00	68.00	8.30	0.12	11.7
Total Hare (6)	8.45	8.45	5.76	68.00	68.00	8.28	0.12	70.0
13) Average Hare	1.20	1.20	0.43	35.80	35.80	5.42	0.18	6.5
Total Hare (4)	4.82	4.82	1.74	36.10	36.10	5.39	0.19	26.0
14) Average Beaver	6.78	5.37	1.20	17.70	22.35	2.20	0.45	15.0
Total Beaver (3)	20.32	16.07	3.59	17.69	22.31	2.20	0.45	45.0
15) Average Beaver	8.60	8.50	1.68	19.53	19.76	2.05	0.49	17.7
Total Beaver (3)	25.80	25.54	5.03	19.50	19.69	2.05	0.49	53.0

APPENDIX B

Weight of summer prey animals consumed by captive wolves and the number of scats/kg prey produced from each feeding trial.

Prey per Trial	Month of Year Prey Killed	Weight of Prey (kg)		No. Scats pr/kg Prey
		Total	Eaten	
Deer Fawn	July	6.35	6.35	2.52
Deer Fawn	July	10.37	10.37	2.12
Deer Fawn	August	18.96	18.96	8.07
Deer Yearling	June	31.30	31.00	1.69
Adult Deer	May	39.55	35.37	2.17
Adult Deer (w/2 fetuses)	May	40.27	40.27	1.64
Adult Deer	May	41.00	39.86	1.10
Adult Deer	September	65.50	57.48	1.56

APPENDIX C

Weight of winter prey animals consumed by captive wolves and the number of scats/kg prey produced from each feeding trial.

Prey per Trial	Month of Year Prey Killed	Weight of Prey (kg) Total	Weight of Prey (kg) Eaten	No. Scats per kg Prey
Average Hare		1.20	1.20	5.42
Total Hare (4)	November	4.82	4.82	5.39
Average Hare		1.41	1.41	8.30
Total Hare (6)	November	8.45	8.45	8.28
Average Beaver		6.78	5.37	2.20
Total Beaver (3)	February	20.32	16.07	2.20
Average Beaver		8.60	8.50	2.05
Total Beaver (3)	February	25.80	25.54	2.05
Deer Fawn	February	25.00	19.55	1.34
Adult Deer	October	74.09	29.82	0.50
Moose Calf	February	183.59	106.49	0.48

APPENDIX D

Assimilation Efficiency of a Captive Wolf Pack

Assimilation efficiency of wolves eating deer was analyzed in the captive wolf pack. I attempted to calculate the following variables in order to solve the assimilation efficiency equation:

1) Average dry weight of deer scats
2) Kilocalories per 1 gram dry weight of scat
3) % dry weight of deer
4) Kilocalories per kg dry weight of deer

A deer fawn weighing 41.0 kg was used. The average dry weight of scats in grams produced from the carcass was determined by obtaining the wet weight of 10 randomly picked scats, drying them at 60^{o}C for 48 hours to determine their dry weight and then calculating the dry weight of all the scats (Appendix E). The average % dry weight (56%) was used to determine the dry weight of all scats (3845.979 kg).

Kilocalories of 1 gram dry weight of a scat was obtained using a bomb calorimeter. Several samples from each scat were run in the calorimeter, and inconsistent caloric values resulted (Appendix F). Since each scat is composed of such a heterogeneous mixture of materials (hair, bone, and vegetable matter), each of these items probably has a different rate of combustion. Therefore, only the materials in the scat which combust most rapidly were burned with all other compounds remaining in their original state.

APPENDIX E

Calculations made to determine the gram dry weight of all the collectible scats produced from a 41.0 kg deer.

Wet Weight (g) of 10 Random Wolf Scats	Dry Scat Weight (g)	% Dry Scat Weight
122.4	95.4	0.78
111.6	54.4	0.49
81.0	42.0	0.52
144.7	88.1	0.66
99.2	59.4	0.60
79.2	47.7	0.60
77.8	44.7	0.57
161.1	86.2	0.54
60.4	13.9	0.23
84.7	54.3	0.64

$\bar{X}$ Dry Scat Wt. = 56%

Total weight of scats = 6867.80 g
X .56

3845.979 g total dry weight of scats

APPENDIX F

Caloric values of wolf scat samples following deer consumption. Each 1 gram sample was obtained from the same scat.

Sample No.	Heat Capacity Δ E (cal/g)	Quantity (g) of sample Not combusted
1	-78.88	0.4800
2	-4516.63	0.4800
3	-704.89	0.4564
4	-454.37	0.4870