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Food Habits and Energy Utilization of Badgers

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FOOD HABITS AND ENERGY UTILIZATION OF BADGERS

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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FOOD HABITS AND ENERGY UTILIZATION OF BADGERS

Abstract

GRANT K. JENSE

A study was initiated in 1966 to determine food habits and energy utilization of badgers. Digestive tracts were collected in eastern South Dakota from November 1966 to November 1967. A male and a female badger were used for two energy-balance and three digestion trials.

Ground squirrels, mice and rabbits were found to be the most important mammal foods eaten. Birds and eggs were only eaten during spring and summer. Toads and grains were important fall foods. Insects were eaten throughout the year but usually only in trace amounts. However, when available, badgers ate large quantities of beetles and ground-nesting bees. Badgers appeared to be opportunists in selecting their foods.

Energy-balance trials showed energy maintenance requirements of 12-week old badgers decreased as much as 62 percent as animals reached maturity.

Digestibility of proteins, fats, carbohydrates and fibers varied between badgers and among diets. Fats were highly digestible. When total digestible calories were used as a measure of digestibility, there was little difference in capacity between badgers to digest the mink feed, deer muscle, cottontail rabbit and ground squirrel diets.

Badgers remained in good condition during penned trials without a source of water other than contained in feeds.

Ground squirrels were believed to be an important source for fall fat storage in badgers since they constitute a high proportion of the diet, are high in fat content and are readily digested.

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INTRODUCTION

The badger, *Taxidea taxus* (Schreber)[1], has increased in numbers throughout most of its range in the midwest in recent years (Bennitt 1939, Moseley 1934 and Snead and Hendrickson 1942). Moseley (1934) believed that draining and clearing of land, low fur prices and increase of thirteen-lined ground squirrels (*Citellus tridecemlineatus*) and other prey caused the increase in northwestern Ohio. The badger adjusted to land-use changes that occurred in eastern South Dakota since pioneer times and is frequently observed living in close proximity to human dwellings in intensively cultivated farmlands.

The recent pheasant decline in South Dakota renewed economic evaluation of predator control and predator food habits within the state. The South Dakota Department of Game, Fish and Parks initiated a fox-pheasant study in 1964 to determine relationships of red foxes (*Vulpes fulva*) to populations of ring-necked pheasants (*Phasianus colchicus*) and other prey. Two years later the study was expanded to include raccoon (*Procyon lotor*), skunk (*Mephitis mephitis*) and badger, common predators found in eastern South Dakota. Predator control as well as predator and prey censuses for that study provided data for a badger food habits study.

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[1]Scientific names of mammals according to Burt and Grossenheider (1964).

Food habits of badgers have been studied in Iowa by Errington (1937) and Snead and Hendrickson (1942) and in Michigan by Dearborn (1932), but no quantitative food habit studies have been done in South Dakota.

Badgers, as carnivorus animals, are adapted for fasting during bad weather, enduring hunger when learning to become self-sufficient and maintaining their strength and predatory faculties during periods of food scarcity. When food is available they must be able to consume large quantities and rapidly digest and assimilate it (Errington 1967).

Most nutrition studies have been on economically important domestic animals such as cattle and sheep. Recently there has been interest in energy requirements of domesticated carnivores such as the dog and cat, and fur producers such as the fox and mink (*Mustela vison*). Very little work has been done on energy needs of wild carnivores (Golley et al. 1965).

The present study was initiated in 1966 to determine badger food habits, digestibility of selected prey and energy balance.

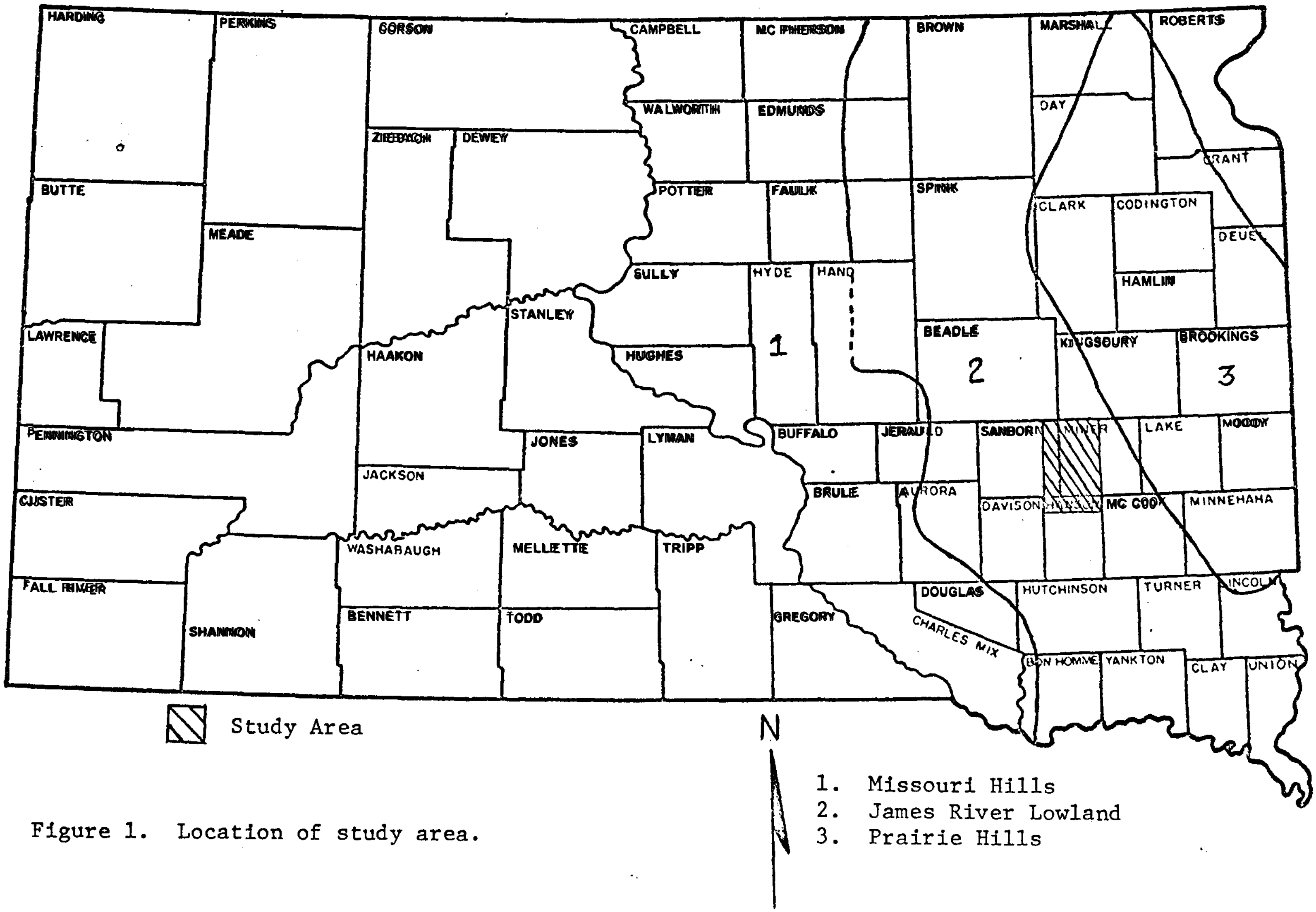
DESCRIPTION OF STUDY AREA

The study area was located in east-central South Dakota in the James River Lowland (Fig. 1), which is lower than the Coteau des Prairies (Prairie Hills) on the east and the Coteau du Missouri (Missouri Hills) on the west. Elevations range from 1,300 to 1,400 feet above sea level. Annual precipitation is 20-22 inches and mean annual temperature is 46-48 degrees F (Westin et al. 1967).

Soils are black and very dark, grayish-brown loams and clay loams developed from calcareous loam till. The area varies from well to moderately well-drained on a gently undulating to nearly level glacial plain (Westin et al. op. cit.). Land use was primarily corn, small grains, pasture and hay (Table 1).

Table 1. Cover types on study area determined from 20 random sections.

Cover Type	Percent
Corn	17.4
Alfalfa	7.1
Small grains	24.1
Grass hay	12.3
Pasture	31.1
Farmstead	.1
Shelterbelt	.7
Other	7.2



1. Missouri Hills
2. James River Lowland
3. Prairie Hills

Figure 1. Location of study area.

The James River Lowland was once covered with mid and tall-grass prairie. Big bluestem (Andropogon gerardi)[1], little bluestem (A. scoparuis), western wheatgrass (Agropyron smithii), sand dropseed (Sporobolus cryptandrus) and switch grass (Panicum virgatum), once plentiful, have largely been replaced by Kentucky bluegrass (Poa pratensis) and smooth brome (Bromus inermis). Trees in the area are restricted to farm yards, shelterbelts and creek banks. American elm (Ulmus americana)[2], cottonwood (Populus deltoides) and green ash (Fraxinus pennsylvanica) are native to the region.

Mammals common to the area are badger, raccoon, striped skunk, red fox, whitetail jackrabbit (Lepus townsendi), eastern cottontail (Sylvilagus floridanus), Richardson ground squirrel or flickertail (Citellus richardsoni), thirteen-lined ground squirrel, deer mouse (Peromyscus maniculatus), and meadow vole (Microtus pennsylvanicus).

A few common birds in the area were ring-necked pheasant, mourning dove (Zenaidura macroura)[3], western meadow lark (Sturnella neglecta), horned lark (Eremophila alpestris), chestnut-collared longspur (Calcarius ornatus) and burrowing owl (Speotyto cunicularia).

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[1]Names of grasses are after Hitchcock (1950).

[2]Names of trees are after Fernald (1950).

[3]Names of birds were taken from the American Ornithologists' Union Checklist (1957).

MATERIALS AND METHODS

Prey Species Abundance

South Dakota Department of Game, Fish and Parks personnel conducted censuses of pheasant (July-Aug.), rabbit (Oct.), and small mammal populations (July) on the study area during 1967 (Trautman and Fredrickson 1968) to estimate relative abundance of prey species. Pheasants and rabbits were censused by roadside counts along selected routes. Small mammals were censused by snap-trapping with 48 traps located'in fence lines of 12 randomly selected sections for 4 days and nights.

It was evident the snap-trap survey was inadequate for censusing ground squirrels. While driving through the study area, the author noted ground squirrels crossing roads and in roadside ditches. These observations suggested a roadside census for ground squirrels and two 18-mile routes were randomly selected. Routes were driven slowly (10-20 m.p.h.) and squirrels were counted on the roadbed, within the road-right-of-way on the left side and in pastures within 50 yards of the road on the driver's side.

After two counts during July 1967, the index was believed adequate, but that spring would be a better time to make counts because of less vegetative cover. Three counts were made when weather conditions favored above-ground activity of squirrels in May 1968.

Badger Food Habits

Badgers were trapped by Kenneth Johnson, state trapper assigned to control and census mammals on the study area. Digestive tracts were removed, put in cloth bags, labeled and preserved in 10 percent formalin. Food items were washed over a 2.38 mm-mesh sieve superimposed upon a 500 micron-mesh sieve. Hair, feathers and finer food items were separated from teeth, bones and other heavier items by flotation in water. Stomach contents were measured volumetrically by water displacement in graduated cylinders after drying in an oven at 100 C until dry. Contents less than .1 milliliter were recorded as a trace.

Frequency of occurrence of food items was determined by dividing number of stomachs or colons containing an item by the total number of stomachs or colons analyzed. Percent volume of stomach contents was volume of an item in all stomachs divided by total volume of stomach contents. Data were tabulated by the three seasons of badger activity: spring (March-May), summer (June-August), and fall (September-November).

Energy Utilization

Two energy-balance trials were run on a male (Fig. 2) and a female badger. Mink feed, obtained from a local mink farm was used for the first trial during June 1967. Deer muscle was used for the second trial during December 1967.

Three digestion trials were run using the same badgers. Mink feed was used the first trial, cottontail rabbit and ground squirrel for the second and third trials. Entire rabbits and squirrels were ground to provide a homogenous mixture. Proximate analysis of feeds and feces was made by Station Biochemistry Department, South Dakota State University.

During the first energy-balance trial, temperature of the laboratory ranged from 72 to 75 degrees F. Temperature was kept lower (47 to 63 F) during the December energy-balance trial because of the heavy winter coat badgers had grown while kept outdoors preceding trial. A wide range of temperatures occurred because of a storm and poorly-insulated building.

Badgers were kept in 24 x 24 x 24-inch cages during the first trial and in 30 x 30 x 18-inch cages in other trials. Cages were designed for separate collection of feces and urine.

Trials were run 10 days except the cottontail digestion trial which lasted 13 days, with at least a 4-day pretrial period. Feed records were kept daily. Water was given ad libitum in the first trial, but was not given in the remainder of the trials. Feces and wasted feeds were collected daily and weighed. Dry weight of wasted feeds was subtracted from dry weight of feed given to obtain daily intake. Urine was collected only during the two energy-balance trials and was measured to the nearest milliliter. Feeds and feces were kept frozen until used or analyzed. Prior to caloric analysis, feeds and feces were oven dried and finely ground in a Waring Blendor and a Labconco burr mill. Urine was stored in a refrigerator, then absorbed in purified cellulose for analysis. All caloric measurements were made with a Parr adiabatic oxygen bomb calorimeter (Fig. 3) using standard methodology, except that sulfur analysis was not run.

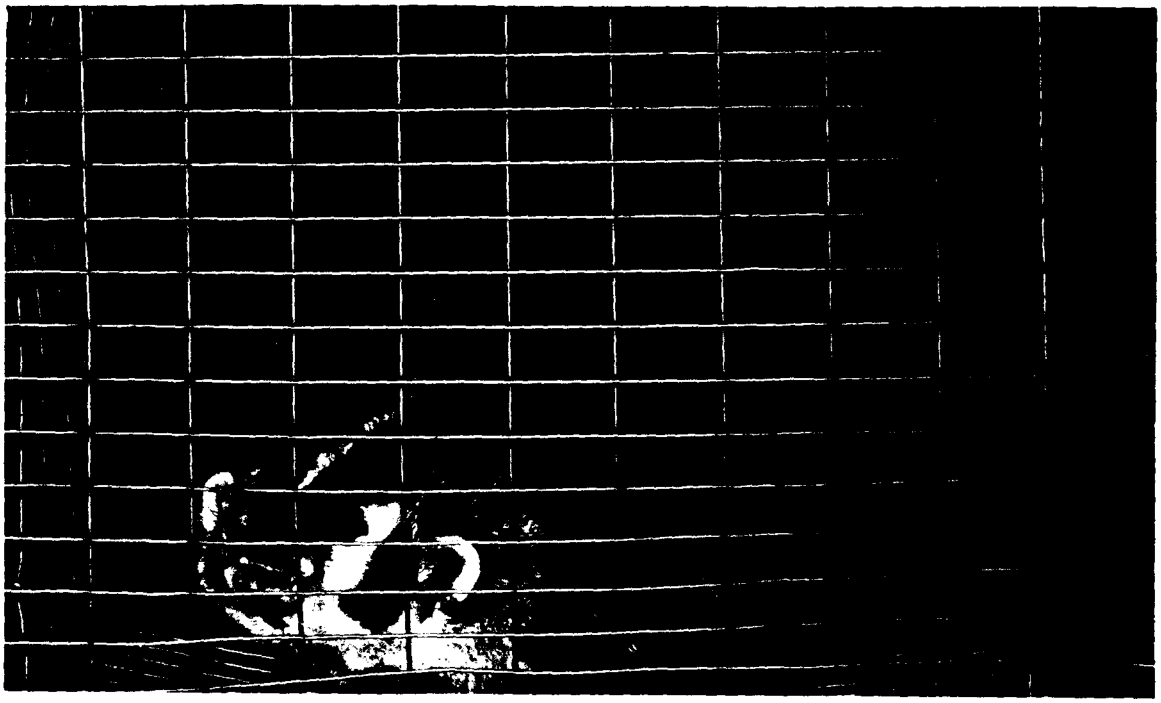

Figure 2. Male badger used in penned studies.

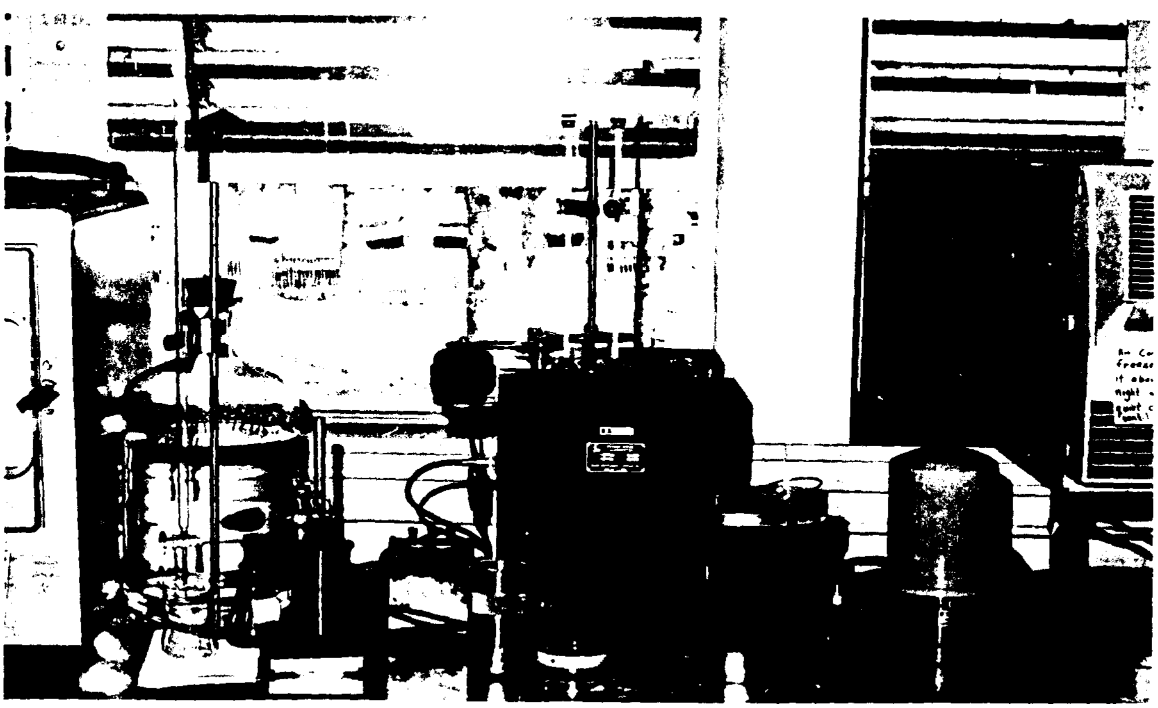

Figure 3. Parr adiabatic oxygen bomb calorimeter used to obtain caloric equivalents.

RESULTS AND DISCUSSION

Badger Food Habits

Prey Species Abundance

Counts showed thirteen-lined ground squirrels were more plentiful and evenly distributed than Richardson ground squirrels (Table 2). Few cottontails were observed compared to jackrabbits, which may be partially due to habitat preference, observability and mobility. Deer mice were the most common small mammal snap-trapped. Meadow voles were believed to be the second most plentiful mouse (Table 3). Drieslein (1967) believed snap-trapping voles did not result in a true estimate of their abundance because voles have a tendency to travel in runways.

Table 2. Animals counted per mile on study area.

Species		Month	Numbers
Ground squirrels	Thirteen-lined	May-July	1.08
	Richardson		0.01
Rabbits*	Jackrabbit	October	4.07
	Cottontail		0.23
Pheasants*	Adults	Jul.-Aug.	1.20
	Young		2.43

* From Trautman and Fredrickson (1968).

Table 3. Small mammals snap-trapped on study area during July 1967 (Trautman and Fredrickson 1968).

Species	Numbers Trapped
Thirteen-lined ground squirrel (C. *tridecemlineatus*)	17
Meadow vole M. *pennsylvanicus*)	11
Masked shrew (*Sorex cinereus*)	1
Grasshopper mouse (*Onychomys leucogaster*)	11
House mouse (*Mus musculus*)	1
Meadow jumping mouse (*Zapus hudsonius*)	2
Shorttail shrew (*Blarina brevicauda*)	3
Western harvest mouse (*Reithrodontomys megalotis*)	1
Deer mouse (P. *maniculatus*)	114
Total	161

Digestive Tract Analysis

From March to November 1967, 119 badgers were trapped on the study area. Food material was found in 50 stomachs and 90 colons. From November 1966 to September 1967, 24 additional digestive tracts were acquired from trapped, shot or road-killed badgers in eastern South Dakota exclusive of the study area. Food items were found in 12 stomachs and 20 colons. Of the 143 digestive tracts, 62 stomachs and 115 colons contained food items. Some animals had food items in both stomach and colon while others had food items only in the stomach or colon. Alimentary tracts from some animals were empty.

Mammals: Mammals were the most important food for badgers throughout the year (Table 4). Badgers, because of their body structure and agility, are able to catch small mammals by digging, but less able to capture abundant prey species such as birds.

Mice were an important staple during spring, comprising 44.1 percent by volume of stomach contents and occurring in 75.0 percent and 75.6 percent of stomachs and colons respectively. Occurrence and volume of mice in the badger diet decreased to a low during summer months, but increased again in fall. Although fall sample size was small and October and November were not represented well, it appeared badgers relied heavily on mice during fall as well as spring.

As many as nine mice were found in a stomach, indicating badgers may spend considerable time hunting them. Evidence of this was observed in freshly-harvested grain fields and around haystacks, where mice tended to concentrate.

Deer mice and meadow voles were the most common mice in the badger diet. They were the most common mice snap-trapped and therefore, probably eaten because of availability and not selectivity. Other species of mice were trapped less frequently and were of minor importance in the diet.

Errington (1937) and Snead and Hendrickson (1942), showed that thirteen-lined ground squirrels were an important food item in the

Table 4. Badger food habits shown as percent frequency of occurrence for stomach and colon contents and percent volume for stomach contents.

Food Item	Spring			Summer			Fall		
	Stomach (20)*		Colon (41)	Stomach (29)		Colon (52)	Stomach (13)		Colon (22)
	Freq.**	Vol.***	Freq.	Freq.	Vol.	Freq.	Freq.	Vol.	Freq.
MAMMALS	90.0	88.1	92.7	79.3	87.9	80.8	69.2	41.6	81.8
Mice	75.0	44.1	75.6	20.7	6.6	38.5	38.5	12.6	68.2
Meadow vole	35.0	10.2	29.3	6.9	5.6	7.7	7.7	1.5	20.0
Deer mouse	55.0	33.9	39.0	3.4	.7	11.5	38.5	9.9	9.1
Harvest mouse						3.9			4.6
Meadow jumping mouse							7.7	1.2	
Undetermined Cricetidae	10.0	Tr.	14.6	3.4	.3	5.8			4.6
Unident. mice	10.0	Tr.	9.8	6.9	Tr.	3.6	7.7	Tr.	40.8
Ground squirrels	25.0	25.2	17.1	62.1	63.5	53.9	23.1	22.8	18.2
13-lined	20.0	23.4	2.4	44.8	46.0	9.6	23.1	22.8	13.6
Richardson			2.4	3.4	7.0				
Unidentified	10.0	1.8	12.2	10.3	10.5	44.2			4.6
Rabbits	20.0	18.8	14.6	10.3	17.8	7.7	7.7	6.0	
Cottontail	15.0	16.5	9.8	10.3	17.8	1.9			
Whitetail jackrabbit	10.0	2.3	4.9			1.9	7.7	6.0	
Unidentified						3.9			
Badger	10.0	Tr.				1.9	15.4	.2	
Pocket gopher			2.4						
Unident. mammal	10.0	Tr.		3.4	Tr.	3.9			

Table 4. (continued)

Food Item	Spring Stomach (20)* Freq.**	Spring Stomach (20)* Vol.***	Spring Colon (41) Freq.	Summer Stomach (29) Freq.	Summer Stomach (29) Vol.	Summer Colon (52) Freq.	Fall Stomach (13) Freq.	Fall Stomach (13) Vol.	Fall Colon (22) Freq.
BIRDS	15.0	2.2	12.1	20.7	5.2	15.4			
Game bird	5.0	2.2	7.3						
Non-game bird	10.0	Tr.	2.4	13.8	5.2	5.8			
Unidentified			2.4	6.9	Tr.	9.6			
EGGS	15.0	Tr.	22.0	34.5	2.1	30.8			
Game bird	5.0	Tr.	7.3	24.1	1.0	15.4			
Non-game bird		Tr.	4.9	3.4	.8	9.6			
Unident. bird	10.0	Tr.	9.8	6.9	.3	3.9			
Reptilian						1.9			
AMPHIBIANS (Toads)				3.4	Tr.		46.2	26.3	
UNIDENT. VERTEBRATE			2.4	3.4	.2	1.9	7.7	.7	4.6
INSECTS	15.0	Tr.	31.7	51.7	2.6	57.7	38.5	Tr.	63.6
Beetles	10.0	Tr.	21.9	41.4	1.7	32.7	38.5	Tr.	36.4
Scarabaeidae	5.0	Tr.	21.9	13.8	1.7	32.7	7.7	Tr.	9.1
Carabidae				3.4	Tr.	5.8	10.3	Tr.	31.8
Other				3.4	Tr.	1.9			22.7
Unidentified	5.0	Tr.		20.7	Tr.	7.7	7.7	Tr.	22.7
Grasshoppers			2.4	27.6	.Tr.	15.4	15.4	Tr.	45.5
Crickets				6.9	Tr.				13.6
Other insects	5.0	Tr.	2.4	27.6	.9	14.4	23.1	Tr.	9.1
Unidentified insects			7.3	3.4	Tr.	9.6			9.1

Table 4. (continued)

Food Item	Spring			Summer			Fall		
	Stomach (20)*		Colon (41)	Stomach (29)		Colon (52)	Stomach (13)		Colon (22)
	Freq.**	Vol.***	Freq.	Freq.	Vol.	Freq.	Freq.	Vol.	Freq.
PLANTS	85.0	9.7	90.2	79.3	2.0	75.0	76.9	31.4	81.8
Grasses	75.0	Tr.	70.7	62.1	Tr.	61.5	46.2	.2	54.6
Corn	5.0	1.2	9.8	3.4	Tr.		15.4	26.5	9.1
Small grains	5.0	Tr.	2.4	10.3	1.7	9.6	7.7	4.7	9.1
Weed seeds	15.0	8.5	17.1			5.8	7.7	Tr.	18.2
Green plant debris	5.0	Tr.	34.2	3.4	Tr.	51.2			50.0
Other			2.4	6.9	Tr.	3.8			
Unidentified			7.3	6.9	.3	5.7			4.6
		100.0			100.0			100.0	

* Number of badger stomachs or colons examined which contained food.
** Percent frequency of occurrence.
*** Percent volume.

diet of badgers in the midwest. Moseley (1934) believed that increase in badger numbers in parts of its range was partially due to increase of thirteen-lined ground squirrels effected by land-use changes. In this study thirteen-lined ground squirrels were an important food item by volume during all three seasons. They were most frequently eaten during summer months, when they were most active and plentiful. Richardson ground squirrels were of minor importance in the diet because of lower numbers and more extensive burrow systems.

Numerous field observations were made of badgers preying upon or attempting to prey upon ground squirrels. In some instances, ground squirrel nests were dug out, while at other times the burrow was deeper or longer than the badger's digging. Several holes dug in hard-packed gravel roads were evidence of the eagerness with which badgers sought thirteen-lined ground squirrels (Fig. 4).

Rabbits ranked third in importance in the diet of badgers. They were eaten more frequently during spring and summer months when young rabbits were available. Two stomachs contained three and five young cottontails (Fig. 5) and another contained a young jackrabbit. Young cottontails were probably taken from nests. A badger would not normally be able to catch adult rabbits, but rabbits are frequently killed by automobiles. Cottontails, jackrabbits, skunks, raccoons, foxes and burrowing owls use badger

Figure 4. Digging of badger searching for thirteen-lined ground squirrels in gravel road.

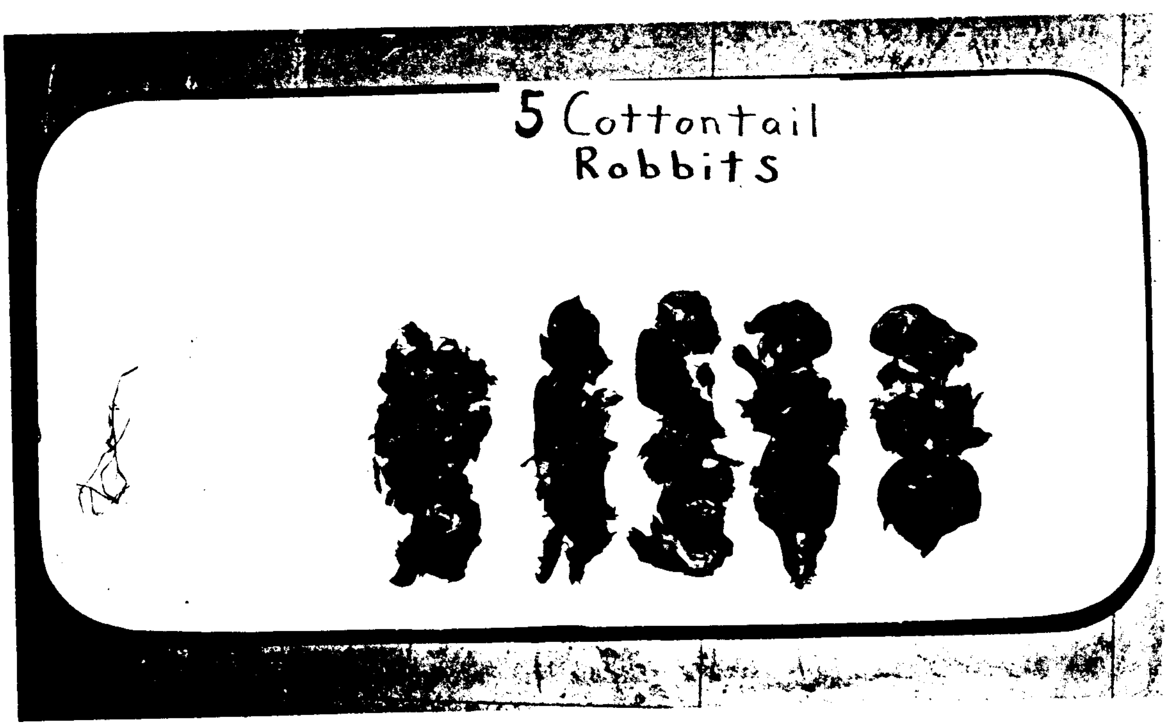

Figure 5. Five young cottontail rabbits found in a badger stomach.

holes as dens or hiding places. Badgers frequently revisit their old diggings and any animal trapped in a hole would be potential food.

Badger remains in stomachs consisted of toes and claws, and were due to self mutilation while in the trap. Badgers are not as apt to bite their trapped-foot as some other mammals, but occasionally one will chew off its toes.

Sign left by pocket gophers (*Geomys bursarius*) was not common in the study area and remains of only one gopher was found in a colon. Snead and Hendrickson (1942) also found pocket gophers to be unimportant in the badger diet.

Birds: Remains of birds and their eggs were arbitarily classified into three categories: game birds, non-game birds and unidentified. Remains of game birds were found only during spring, when three adult pheasants were eaten. Non-game birds included chickens and various ground-nesting passerine birds such as meadow larks, horned larks and longspurs. Unidentified bird remains usually consisted of a few feathers. Most birds are likely taken when the opportunity occurs while the badger is seeking other prey (Errington 1937).

Eggs: Eggs were eaten only when they were available during the nesting period, in spring and summer. Although occurrence of eggs was as high as 34.5 percent in the stomach and 30.8 percent in the colon during the summer, they made up only 2.1 percent of the volume. This was due to rapid and nearly complete digestion. It is not possible to determine the number of eggs eaten since little of the shell is normally consumed. However, a badger will usually consume the contents of all the eggs in a nest and this amounts to a substantial quantity when a dozen or more pheasant or duck eggs are eaten.

Game-bird eggs were from pheasant except for duck eggs in two digestive tracts. Some of the unidentified eggs may have been pheasant eggs, but positive identification could not be made. One stomach contained eggs with well-developed pheasant chicks, but it could not be determined if the remainder of the eggs contained embryos or were from abandoned or dump-nests. Nineteen percent of 134 pheasant nests on the study area were destroyed by badgers, according to summer employees of the Department of Game, Fish and Parks (Trautman and Fredrickson 1968).

Amphibians: Toads (*Bufo cognatus*) occurred in 46.2 percent of stomachs and comprised 26.3 percent of volume for fall months. Only a trace of one toad was found in late summer. Heavy rains during June 1967 provided conditions for a successful toad hatch. Near the vicinity of water, innumerable small toads were seen crossing roads in the study area. Toads were observed to use badger burrows for places to hide and possibly hibernate. Badgers had ample opportunity to feed on them during the latter part of summer, but it was fall before toads appeared in the diet in appreciable amounts, when as many as 25 small toads were found in a stomach. This might be a reflection of scarcity of other foods. Errington (1967: 29) probably had the same thoughts in mind when he said, "In common with almost all other north-central flesheaters, minks patently do not relish toads".

Insects: Fragments of various insects were present in trace amounts throughout the year. Finely chewed insects found with small rodent remains and ants found in stomachs containing toads, indicated some insects were from ingested prey species. May beetles (*Phyllophaga* sp.), both adults and white grubs, were considered the most important insect in the diet. A colon collected in September contained 199 white grubs, indicating badgers may spend considerable time searching for these insects. On several occasions, the author observed pastures in which sod had been rolled by badgers in search of white grubs. Badgers were noted to either turn over or roll large pieces of sod.

Grasshoppers were frequently eaten, but only in trace amounts. Two to three hundred snout beetles (*Sitonia* sp.) were found in a stomach and colon from August and part of a nest of a ground-dwelling bee containing several pupae and larvae was found in a July stomach, indicating that when the opportunity arises, badgers will eat insects in large quantities.

Plants: Grasses, usually dry and in trace amounts, were frequently consumed during all seasons. They were probably ingested incidentally with other foods. Weed seeds were probably in the small mammal and bird prey, except for one stomach taken in the spring which was gorged with seeds of annual sunflower (*Helianthus annuus*). During fall, 31.2 percent of the volume of 13 stomachs was corn and small grains. Badgers seemed to consume more of this plant material when animal foods were not as easily obtained.

Many stomachs contained dirt, sand and small rocks and a majority of the scats in the colons contained clay or sand. This would be expected of an animal that captures most of its prey by burrowing.

Parasites: Ninety-three percent of stomachs and 26 percent of colons harbored roundworm parasites. *Physaloptera maxillaris*, P. *torquata* and *Ascaris columnaris* comprised the majority of roundworms. Larvae and adults of P. *maxillaris* were most common, with as many as 104 one-fourth to one-half inch larvae present in a stomach. One badger trapped early in the spring contained several 6-8 inch long A. *columnaris*, which nearly blocked the intestine. Only one tapeworm (*Taenia* sp.) was found in a colon. However, since the small intestine was not examined, this would not be representative of tapeworm. infection in badgers.

Energy Utilization

Caloric equivalents in calories per gram (Table 5) were obtained for excretory products and all feeds except deer meat. Colley et al.

Table 5. Caloric equivalents (Kcal/g *dry* weight) of feed and excretory products during badger trials.

Source of Calories	Female	Male
Mink Feed Diet		
Feed	4.911	4.911
Feces	3.421	3.390
Urine (Kcal/ml)	.089	.112
Deer Meat Diet		
Meat	5.657*	5.657*
Feces	5.094	5.961
Urine (Kcal/ml)	.604	.673
Cottontail Rabbit Diet		
Rabbit	5.441	5.441
Feces	3.532	3.689
Ground Squirrel Diet		
Squirrel	5.132	5.132
Feces	2.722	2.722

* Assumed to be the same as that obtained by Colley (1965).

(1965: 444) reported energy content per gram of lean deer muscle tissue was 5.657 Kcal/g. Weight gained during the first energy-balance trial, while badgers were young, was assumed to be normal body growth. Caloric value for body growth was assumed to be 5.7 Kcal/g which Brody (1945) gave for mammalian muscle tissue. Weight gained during the December energy-balance trial, when badgers were adult size, was assumed to be fat deposition. Crampton (1956) gave 9.3 Kcal/g as caloric value for fat. All caloric equivalents were on a dry-weight base except urine. Dry weight of badger muscle tissue was assumed to be 25 percent and fat 85 percent of wet weight. Values were converted to Kcal/Kg body weight/day for comparisons among diets and between badgers.

Although the male consumed approximately the same as the female, conversion to a Kcal/Kg/day intake basis showed a lower energy intake per body weight. This was due to feeding procedure and not to consumption by the animals.

Water was given ad libitum only during the first energy-balance trial. Because badgers had a tendency to spill water it was not furnished during remaining trials. Schwartz and Schwartz (1959: 293), while discussing the needs of badgers for water said, "In the wild, badgers do not seem to require water to drink since they often live far from any surface source; in captivity, they drink water regularly." Water from prey species and from metabolism apparently sufficed their needs under penned conditions of these trials. The caged animals urinated daily, gained weight, maintained a very good coat and generally appeared in excellent condition.

<u>Energy Trials</u>

The two badgers were approximately 12 weeks old at the beginning of the first energy-balance trial and 35 weeks old at the beginning of the second energy-balance trial (Table 6). During the period between trials, daily maintenance requirements of the male decreased 55 percent (101.77 to 45.83 Kcal/Kg/day) and the female 62 percent (117.70 to 44.98 Kcal/Kg/day). A trend in decrease of energy required for maintenance is generally true for most mammals as they grow larger and older. Smith (1935) found that 5-month old silver fox pups required 750 calories daily, approximately one and one-half times the quantity (95 to 100 Kcal/Kg/day) needed for the average adult fox. He stated that caloric requirements of foxes are dependent upon body area rather than live weight, which Brody (1945: 354) believed to be true for most mammals. Since badgers have a more stocky build than foxes, the ratio of surface area to body weight would decrease even more with growth, lowering energy maintenance requirements per kilo of body weight. Golley et al. (1965) using bobcats that ranged in weight from 2.72 to 8.84 Kg, found a variation from 52 to 151 Kcal/Kg/day for maintenance. The lowest values, 52 and 66 Kcal/Kg/day, were obtained on two animals weighing 5.62 and 6.36 Kg

Table 6. Energy balance for penned badgers expressed as Kcal/Kg body weight/day.

Sex	Diet	Days on Experiment	Weight (Kg) Beginning	Weight (Kg) End	Energy Intake
Female	Mink Feed	10	4.34	5.12	170.00
Male	Mink Feed	10	4.25	4.98	149.73
Female	Deer Meat	10	8.10	8.25	70.11
Male	Deer Meat	10	10.56	10.58	57.27

Sex	Diet	Feces		Urine		Weight Gain		Maintenance*	
		Per Kg	Percent	Per Kg	Percent	Per Kg	Percent	Per Kg	Percent
Female	Mink Feed	27.90	16.41	2.58	1.52	21.83	12.84	117.70	69.23
Male	Mink Feed	23.57	15.74	3.66	2.44	20.72	13.83	101.77	67.97
Female	Deer Meat	1.61	2.30	8.72	12.44	14.79	21.10	44.98	64.16
Male	Deer Meat	1.84	3.21	6.88	12.01	2.71	4.73	45.83	80.04

* Maintenance calculated by difference.

respectively. Both of these animals were adult size and were fed a deer meat diet similar to that fed the two badgers. Whether the lower maintenance value for the two badgers during the second trial was partially due to the diet itself is not known.

Energy lost in urine differed considerably between the two energy-balance trials. The difference was believed to have resulted from plane of nutrition. The mink feed diet contained about 30 percent protein while deer muscle tissue was high in protein, resulting in a substantially higher proportion of protein metabolites in the urine (Brody 1945: 353).

Energy lost in fecal excretion showed an inverse relationship to loss in urine. This was due to difference in digestibility of the two diets. The deer meat diet was about 98 percent digestible, while the mink feed was only about 84 percent.

An average of 13 percent of daily intake on the mink feed diet went to weight gain. Since the badgers were young and growing rapidly at that time, a gain of .78 Kg by the female and .73 Kg by the male was body growth. Although 21.1 percent and 4.73 percent of the daily energy intake for the female and male respectively was accounted for by weight gain during the second trial, it only represented a .15 Kg and .02 Kg gain in weight. Gain was considered to be fat deposition and represented larger calorie storage per gram than during body growth.

A badger not only has to consume enough feed to provide for daily maintenance and energy to acquire the next meal, but also be efficient in digestion and utilization of feeds in order that a surplus may be stored in the form of fat for the inactive period during winter. Badgers that go into winter without sufficient fat stores will likely be more affected by cold temperature and parasite infections.

Digestion Trials

Results of three digestion trials (Table 7) showed a variation between individual badgers in capability to digest proximate factors of different diets. Variations among diets usually are due to difference in digestibility of constituents derived from different sources. Digestion trials on mink by Hodson and Maynard (1938) using six different diets showed variations in digestibility of proximate factors among diets with similar results obtained for the three badger digestion trials.

Capacity of badgers to digest fat from such prey species as the thirteen-lined ground squirrel provides valuable fat stores for winter (Table 7). Since timing of hibernation by ground squirrels is regulated by thickness of their fat layer (Schwartz and Schwartz 1959 and Gunderson 1961), they would contain 1/3 to 1/2 more fat in fall than spring, when the squirrels were obtained for this study. Therefore, they would contain a higher percent

Table 7. Badger digestion trials showing proximate analysis of feeds and feces and percent digestibility.

	Mink Feed Diet*					
	Female Badger			Male Badger		
Analysis	Feed	Badger Feces	Percent Digested	Feed	Badger Feces	Percent Digested
Ether Extract (Fats)	18.64% 330.37g	.89% 3.72g	98.98	18.64% 283.02g	3.31% 11.46g	95.95
Crude Fiber	3.57% 63.27g	11.38% 49.39g	21.94	3.57% 54.21g	10.92% 37.82g	30.22
Crude Protein	29.97% 531.17g	23.31% 97.33g	81.67	29.97% 455.05g	20.67% 71.50g	84.27
Ash	8.33% 147.64g	21.46% 89.60g	**	8.33% 126.48g	15.85% 54.90g	**
Nitrogen-Free Extract (Carbohydrates)	39.49% 699.90g	42.51% 177.50g	74.64	39.49% 599.60g	49.25% 170.58g	71.55

* All figures are for dry weights - feed was originally 66.63% water.

Table 7. (continued)

	Cottontail Rabbit Diet*					
	Female Badger			Male Badger		
Analysis	Feed	Badger Feces	Percent Digested	Feed	Badger Feces	Percent Digested
Ether Extract (Fats)	21.23%	30.06%	97.76	21.23%	2.62%	97.56
	297.54g	11.52g		289.43g	9.42g	
Crude Fiber	1.92%	5.03%	29.63	1.92%	4.66%	35.98
	26.97g	18.94g		26.18g	16.76g	
Crude Protein	66.84%	53.51%	78.50	66.84%	48.34%	80.83
	936.76g	201.45g		911.23g	173.81g	
Ash	10.51%	26.51%	**	10.51%	31.34%	**
	147.30g	98.45g		143.28g	112.68g	
Nitrogen-Free Extract (Carbohydrates)	00.00%	12.25%	***	00.00%	13.04%	***
	00.00g	46.12g		00.00g	46.89g	

* All figures are for dry weights - rabbit was originally 67.85% water.

Table 7. (continued)

	Ground Squirrel Diet*					
	Female Badger			Male Badger		
Analysis	Feed	Badger Feces	Percent Digested	Feed	Badger Feces	Percent Digested
Ether Extract (Fats)	28.77% 411.04g	2.32% 5.63g	98.63	28.77% 450.62g	1.49% 3.44g	99.24
Crude Fiber	1.20% 17.14g	2.64% 6.41g	62.60	1.20% 18.68g	2.42% 5.58g	51.20
Crude Protein	58.38% 834.08g	45.04% 109.33g	86.89	58.38% 914.41'g	41.70% 96.21g	89.48
Ash	10.00% 142.87g	42.83% 103.97g		10.00% 156.63g	47.71% 110.08g	**
Nitrogen-Free Extract (Carbohydrates)	1.65% 23.57g	7.17% 17.40g	26.18	1.65% 25.84g	6.68% 15.41g	40.36

* All figures are for dry weights - squirrel was originally 63.24% water.
** Not calculated because of excretion into the intestine.
*** See digestion trial discussion.

of fat when needed by badgers acquiring their own fat stores. The high percent of protein contained in prey species would be valuable to growing badgers, but would not be as useful as fat for an energy source or for fat deposition.

As seen by the proximate analysis of cottontails and ground squirrels, there is little if any nitrogen-free extract (carbohydrates) available in animals eaten by badger. Carbohydrates in the mink feed diet were added in the form of cereals, which are a cheaper source of energy than animal feeds. The female and male badger were able to digest 78.5 and 80.8 percent respectively of this energy source. Negative values found for nitrogen-free extract in the cottontail diet is not readily explainable. In some instances, bacteria may make up a considerable portion of the dry weight of feces. This may or may not have been the reason for the negative value in that trial. Mustelids have a relatively short intestine of low capacity and there is little digestion of fibrous materials and certain carbohydrates as occurs in the intestine of herbivores. However, there is a difference in capacity between individual carnivores of the same species to digest fibrous material as can be seen in these trials. Badgers may also receive vegetable matter in different stages of digestion from the intestines of prey species, which could be a source of carbohydrates.

Digestibility is not calculated for ash, because of excretion into the intestine of minerals that have already been used by the body. Ash in the above diets was derived mostly from ground bones of prey species.

When total digestible calories are used as a measure of digestibility (Table 8), there is little difference in the ability of the two badgers to digest various foods. Much of the undigested portion of the ground squirrel and cottontail was made up of hair, which is a source of calories unavailable to badgers, but is included for total calories in a dry gram of ground squirrel or rabbit.

Table 8. Percent digestibility of feeds used for trials.

Diet	Source of Calories	Male (Kcal)	Female (Kcal)
	Rabbit consumed	7,418.02	7,625.87
Cottontail	Feces excreted	1,326.51	1,329.69
rabbit	Digestible calories	6,091.51	6,296.18
	(Percent digested)	(82.12)	(82.56)
	Meat consumed	6,058.89	5,783.74
Deer meat	Feces excreted	194.93	132.95
	Digestible calories	5,963.96	5,650.79
	(Percent digested)	(98.43)	(97.70)
	Feed consumed	7,456.63	8,704.03
Mink feed	Feces excreted	1,174.12	1,428.45
	Digestible calories	6,28.2.51	7,275.58
	(Percent digested)	(84.25)	(83.59)
	Squirrel consumed	8,038.25	7,332.09
Ground	Feces excreted	628.01	660.73
squirrel	Digestible calories	7,410.23	6,671.35
	(Percent digested)	(92.19)	(90.99)

CONCLUSIONS

Ground squirrels, mice and rabbits were found to be important mammal foods in the badger diet. Thirteen-lined ground squirrels were found to be far more abundant and evenly distributed on the study area than the Richardson ground squirrel. Thirteen-lined ground squirrels also comprised the majority of ground squirrel in the diet. There was an inverse relationship in amount of ground squirrels and mice eaten. Mice were eaten more frequently during spring and'fall while ground 'squirrels were eaten in greater quantity during summer. This may be due to a preference for ground squirrels when available or a matter of energy output required for the amount of food received. Rabbits occurred in the diet most frequently during spring and summer months when road-kills and young were most plentiful. Birds and eggs were represented in the diet only during the breeding and nesting season. Toads and grains occupied a higher percent of the volume of food eaten during fall, which is probably because of a growing scarcity of other foods. Insects were frequently eaten during all seasons but usually only in trace amounts.

The above findings are similar to those found by Errington (1937) and Snead and Hendrickson (1942) in Iowa. Results strongly suggest that the badger, like most predators, is an opportunist and eats what is available.

Findings of two energy-balance trials indicate that daily maintenance requirements decrease as much as 62 percent as badgers mature. Decrease in energy needs of maturing animals was believed to be due to a decrease in the ratio of body surface area to body weight. Golley et al. (1965: 444), while working with bobcats, obtained low maintenance values when using deer muscle. Therefore, lower values obtained for the second badger energy-balance trial may have been partially due to diet used. Amount of energy lost in urine and feces was found to be related to the plane of nutrition. Amount of weight gained during trials was proportional to amount of energy intake beyond daily maintenance requirements and that lost in excretion.

Results of digestion trials showed variation between the male. and female in ability to digest proximate factors of feed. There was also a difference in digestibility of proximate factors of different diets. However, when total digestible calories were used for a measure of digestibility, there was little difference between the two badgers.

Ground squirrels were believed to be an important source for fall fat storage in badgers, since they constitute a high proportion of the diet, are high in fat content and are readily digested.

Using results from energy-balance trials and relating them to food habits of badgers, conclusions can be made concerning amount and quality of daily food an animal must ingest in order to maintain itself. For example, using an 8.25 Kg female badger and cottontail rabbit as the prey, a total of 371.1 Kcal would be needed daily. Thirteen rabbits used for the cottontail digestion trial weighed an average of 2.58 pounds. Knowing that the rabbits were 67.9 percent water, contained 82.56 percent digestible calories and that one gram of rabbit contained 5.441 Kcal, it can be calculated that 82.6 dry grams or 21.9 percent of a whole rabbit would be needed per day. In the ground squirrel 72.3 digestible grams would be needed per day to meet maintenance requirements. These figures are minimal and based on minimum activity. If the energy a badger expends daily digging for prey is considered, intake may have to be increased several fold.

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