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A PRELIMINARY STUDY OF RETENTION OF HAIR, FEATHERS OR EGG SHELLS IN THE DIGESTIVE TRACTS OF CERTAIN PREDATORY BIRDS AND MAMMALS

By

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INTRODUCTION

The study of pellets and fecal remains has recently become of a great deal of importance in food habits research. Results of the analysis of scats and pellets are undoubtedly of great value as an indication of species eaten, but to date the period of retention of hair, feathers and egg shells in the digestive tracts over known intervals of time and the gradual egestion in feces, or the periodic regurgitation of several pellets from the food eaten, in the case of predatory birds, has been neglected. Data concerning the food habits of the various predators obtained by the examination of scats and pellets, gives a good index to the species taken, but is not a definite indication of the relative numbers taken.

The purpose of this study has been to determine the difference, if any, in the periods of retention of hair, feathers and egg shells among a few of the predators native to the state of Michigan, as well as the difference in retention of the various foods taken by each species.

The results of this study go but a short way to aid in a quantitative interpretation of scat and pellet analysis data. The lack of a sufficient number of individual species of predators, and the limited number of feedings prevents the drawing of any definite conclusions concerning the problem of retention. Certain trends, however, are in evidence.

The purpose of this paper is to report, discuss and present possible explanations of these trends.

REVIEW OF THE LITERATURE

Retention in Mammals

A great deal of work has been done upon the structure and function of mammalian digestive tracts, but reference to any phase of retention of undigestible parts in the digestive tract of the mammalian diet is almost negligible.

In food habits studies, certain investigators, such as Errington (1935), Dearborn (1932), working both with stomach contents and droppings, recognized the fact that retention plays an important part in determining the contents of indigestible material such as hair or feathers in the feces. Other workers, such as Hamilton (1935, 1936), Murie (1936), Selko (1936), did not mention the interpretation retention might exert upon their findings.

Errington (1935) in his study of the food habits of the mid-west foxes writes: "Foods are differentially resistant to digestion and are retained in the stomach for differential periods of time", and continues by saying that although traces are of a great deal of importance in qualitative food habits studies, they are dangerous to use as a quantitative index. As an illustration of his point, he mentions his findings of bones from one bob white quail in five fecal samples of a fox.

Dearborn (1932) adds to Errington's views that a better interpretation of data collected through scat analysis is needed by expressing the opinion that digestion of feathers and hair is not the same in all species. By placing a mink in confinement and feeding it one English sparrow, he found that scats up to the fourth day after feeding contained feathers; feathers were most numerous in the scats of the first and second days and that digestive action had little affect upon the feathers. It was also found that feathers in the fox disintegraded more than those passing through the mink. From these experiments, Dearborn concluded that a single dropping may contain evidence of several meals while several droppings may contain evidence of only one meal.

No discussion of the factors influencing retention of undigestible parts by the digestive tracts of mammalian predators could be found. However, certain studies of human digestion and digestion of domestic animals do cast some light upon the possible causes of retention. Information of this sort is included in a discussion of digestion in mammals as found on pages 39 to 42.

Retention In Hawks And Owls

Errington (1930) found that horned owls ordinarily eject pellets within twenty-four hours after feeding, but do not conform strictly to any schedule in so doing. After the feeding of a pair of scapula from a skinned cat, the bones were disgourged in approximately five hours with all the available meat digested from them (Errington, 1938). While working with the great horned owls, Reed (1928) observed that twelve to twenty hours was the normal range of time involved in the process of digesting material from bones, hair or feathers and ejection of a pellet. Hibbert-Ware, in her work on the little owl in England, found a retention period of usually twenty-four hours. Observations made on the barn owl by Ticehurst (1930) showed that any pellet regurgitated was probably from the feedings of the twenty-four hours before.

Recorded observations of the length of time of retention of pellets in hawks are dearth when compared to those on owls, being largely confined to casual observations made during the progress of other experiments. Errington (1930) mentions the fact that in the case of the red-shouldered and red-tailed hawk, specimens of which were confined in captivity, length of retention of pellets was not dependent upon time, but were regurgitated when just so large. In his studies on the Montague harrier, (Ticehurst, 1936) reached the same conclusion that he did in the case of retention in the barn owl, chiefly, that any pellets disgorged were the results of feedings within the last twenty-four hours.

Several observations of both hawks and owls ejecting more than one pellet from a single feeding have been recorded.

Errington (1930) found that great horned owls sometimes eject two pellets from a single feeding and at other times retain part of a pellet for regurgitation with a pellet of another feeding. Bird (1929) believes that the horned owl upon eating an animal as large as a rabbit will regurgitate several pellets. In her summary of observations of feedings of the little owl, Hibbert-Ware reached conclusions that agree with both Errington and Bird on this matter; namely, that several pellets may be ejected from one feeding either singely or with subsequent pellets, providing the feeding was large enough.

The pellets of birds of prey are formed in the stomach and disgorged by the act of regurgitation, which is evidently closely allied to vomiting in mammals (Reed, 1925). This being the case, a complete study of the digestive tract, which is not involved in most cases of retention, is not as important as a complete study in mammals. A search of the literature revealed that but one study has been made upon the digestive tract of birds of prey in relation to pellet formation, although some closely associated observations have been made. These are included in a discussion of digestion in hawks and owls found on pages 55 to 58.

METHODS OF PRECEDURE

Predators Used

In these experiments, certain animals were confined in cages and fed food containing hair, feathers or egg shells. The feces from these feedings were collected and analyzed for amounts of the above.

A list of the predators used, with other information concerning them, follows:

	Letter*	Age	Weight	Sex	Source
Raccoon	A	Mature		Male	Captive Raised--Pa.
"	E	"		"	" " "
"	H	"		"	" " "
Opossum	O	6--11 Mo.	4.7 lb.	"	Box Trapped--Michigan
"	K	" " "	4.4 "	Female	" " "
Skunk	S	" " "	2.9 "	"	Captive Raised--Michigan
"	D	" " "	3.2 "	"	" " "
Great Horned Owl	G	" " "	2.9 "	(?)	Trapped--Pennsylvania
Barn Owl	B	" " "		Male	Captive Raised--Pa.
Red Shouldered Hawk	R	Immature	2.2	Male	Pole Trapped--Michigan
Barn Owl	C	6--11 Mo.		—	Captive Raised--Pa.

*As a matter of convenience in cataloguing data, a letter was given each animal.

From the tabulation above, it may be noted that several of the animals used were raised in captivity. The affect of this upon the data collected cannot be stated although the digestive function of animals in captivity undoubtedly somewhat parellels digestion of wild animals not in captivity. However, the fact that during the course of the experiments the animals were not confined to their natural habitat, may have some affect upon the results.

Cages

Since existing conditions made it impossible to duplicate natural habitats, each predator was confined to one or both of two types of cages. Type A, indoor cages, were approximately 3' x 3' x 3' with a 1" x ½" diagonal grill as a floor. The bottom of the cages were raised three feet above the level of the floor. Type B, outside cages, consisted of a five cage unit, each cage being 3' x 6' x 6' with a 1" mesh chicken wire floor elevated three feet from the ground. Both types of cages allowed the feces to drop through to a paper spread on the ground or floor from which they were collected.

Feeding

Each feeding of hair, feathers or egg shells, together with subsequent feedings of regular rations, is termed a feeding series. After each feeding, portions not eaten within the course of one or two hours were removed from the cage. Egg shells, which were fed mixed with other food, were at all times readily consumed.

Rations of food, which did not contain hair, feathers or egg shells, were fed at fairly regular intervals throughout the time the scats were collected. These feedings between the ingestion of hair or feathers consisted wholly of beef heart, liver, or the flesh of some small animals in the case of the owls and hawks, and the above kinds of meat and dog food for the mammals.

At the outset of experiments with each of the various predators, test feedings, in which the feces were analyzed from time to time, to determine the probable length of retention were run. The results of the test feedings made it possible to space the feedings in such a way that scats collected for any one feeding series would contain only the hair, feathers or egg shells of that feeding.

In some cases, it was difficult to get the mammals to eat either hair or feathers, or both. This was especially true of the raccoons who seemed to be very adept in partially or sometimes entirely skinning out their prey. It was, therefore, necessary to feed less than the animal would consume in one meal, thereby encouraging the consumption of the entire carcass to satisfy the animal's hunger, or to mechanically discourage the removal of the skin. This was easily accomplished in the case of the raccoons when feeding birds as large as a chicken or pheasant, as follows: By pulling back the skin before severing the legs at the junction of the tibia and acetabulum, the loose ends of the skin could be drawn over the exposed muscles and sewed securely together with strong thread. This had the affect of discouraging the removal of skin and feathers and the eating of only the flesh.

Neither of the skunks nor one of the opposums under observation showed an appetite for small mammals offered as food. It was therefore necessary to first remove the hair from the pelt by skinning it out and soaking it in a lime solution, washing it and then mixing it with dog food. This mixture was readily consumed by the opossum, but rejected by the skunks.

Animals used as food in the course of the experiment were:

Common Name	Scientific Name	Source
Mammals		
House Mouse	Mus musculus	Laboratory Raised
White Footed Mouse	Peromyscus maniculatus	(Laboratory Raised (Field Collected
Field Mouse	Microtus Pennsylvanicus	Field Collected
Common Rat	Rattus norvegicus	Laboratory Raised
Thirteen-Lined Ground Squirrel	Citellus tridecemlineatus-	Field Collected
Red Squirrel	Sciurus hudsonicus	Field Collected
Muskrat	Ondatra zibethicus	Field Collected
Cottontailed Rabbit	Sylvilagus floridanus	Field Collected
Large Brown Bat	Eptesicus fuscus	Field Collected

Common Name	Scientific Name	Source
Birds		
English Sparrow	Passer domesticus	Field Collected
Starling	Stumus v. vulgaris	Field Collected
Mourning Dove	Zenaidura carolinensis macroura	Field Collected
Pheasant	Phasianus colchicus torquatus	Game Farm Birds
Downy Woodpecker	Dryobates pubescens medianus.	Field Collected
Plymouth Rock Chicken	Gallus gallus	Farm Raised

Collecting Scats and Pellets

Scats and pellets were collected as soon after deposition as possible. In all but a few cases only one defecation had taken place prior to collection. In most cases, where more than one deposition had been made, the feces of the two scats were easily distinguishable due to the drying of the first set before the deposition of the second.

Time records on egestion were maintained to the nearest hour when possible. The time of defecation of scats deposited during the night and collected in the early morning was approximated by the amount of drying out that had taken place. In most cases, less than ten hours elapsed between the last collection of the evening and the first collection in the morning. The specimens were then labeled, placed in the open petrie dishes and allowed to air dry for a period of two to three weeks.

Analysis of Pellets and Fecal Samples

Analysis of scats for contents of hair, feathers or egg shells was put on a sample basis. The equipment used included filter paper for each fecal sample, a battery jar of seven thousand cubic centimeter capacity, a sampling tube twenty millimeters long, a small piece of rubber sheeting two and one-half inches square, several glass funnels, a large syringe and an electric egg beater with a glass bowl of three cup capacity. (See illustrations 1 and 2, pp. 12 and 12a.

Prior to analysis, each fecal sample was placed in a one-half pint glass jar and allowed to soak in water for a period of at least twelve hours. After this soaking, the contents of each jar were transferred to the bowl of the egg beater and thoroughly broken up. This process took anywhere from three to eight minutes, depending upon the consistency of the scat.

After the material had been completely dispersed throughout the liquid in the bowel of the egg beater, it was emptied into the battery jar. This was filled with tap water to a volume of four thousand cubic centimeters. Upon standing a few minutes, all movement of hair, feathers or other fecal matter stopped.

As movement of the mixture stopped, the hair, feathers and fecal matter became arranged in a more or less definite order. The highest concentration of hair or feathers remained at the top or close to the top of the liquid. From the surface to three-quarters of the way to the bottom, hair and feathers were found

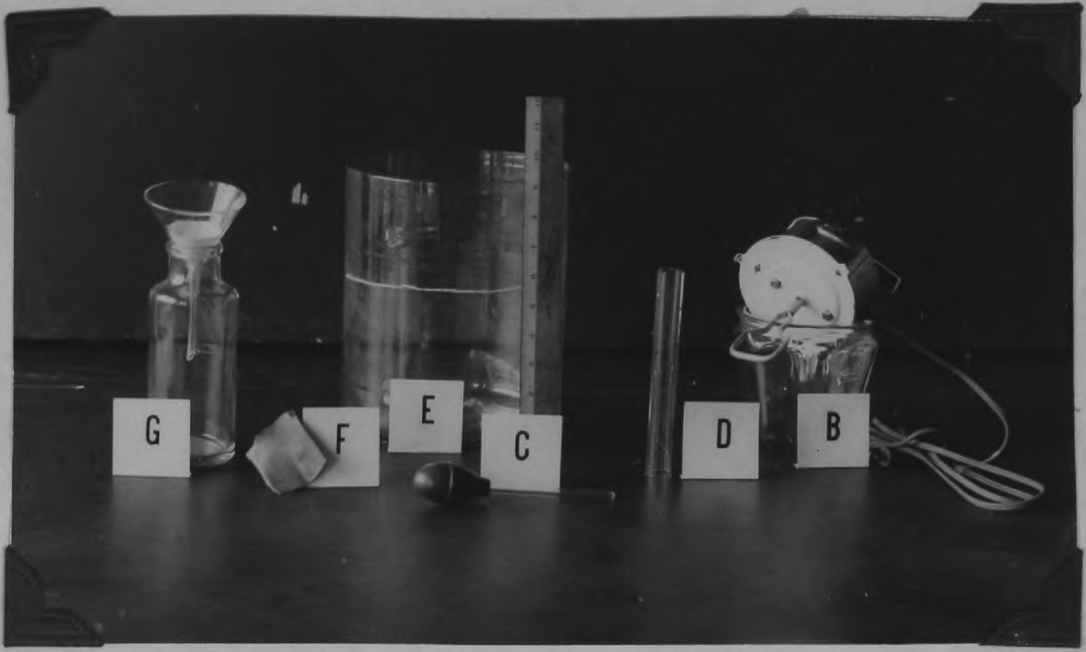


ILLUSTRATION 1. Side View of the Equipment Used in the Analysis of Fecal Samples.

LEGEND

B Electric Egg Beater

C Syringe

D Sampling Tube

E Battery Jar

F Rubber Sheeting

G Funnel with Filter Paper

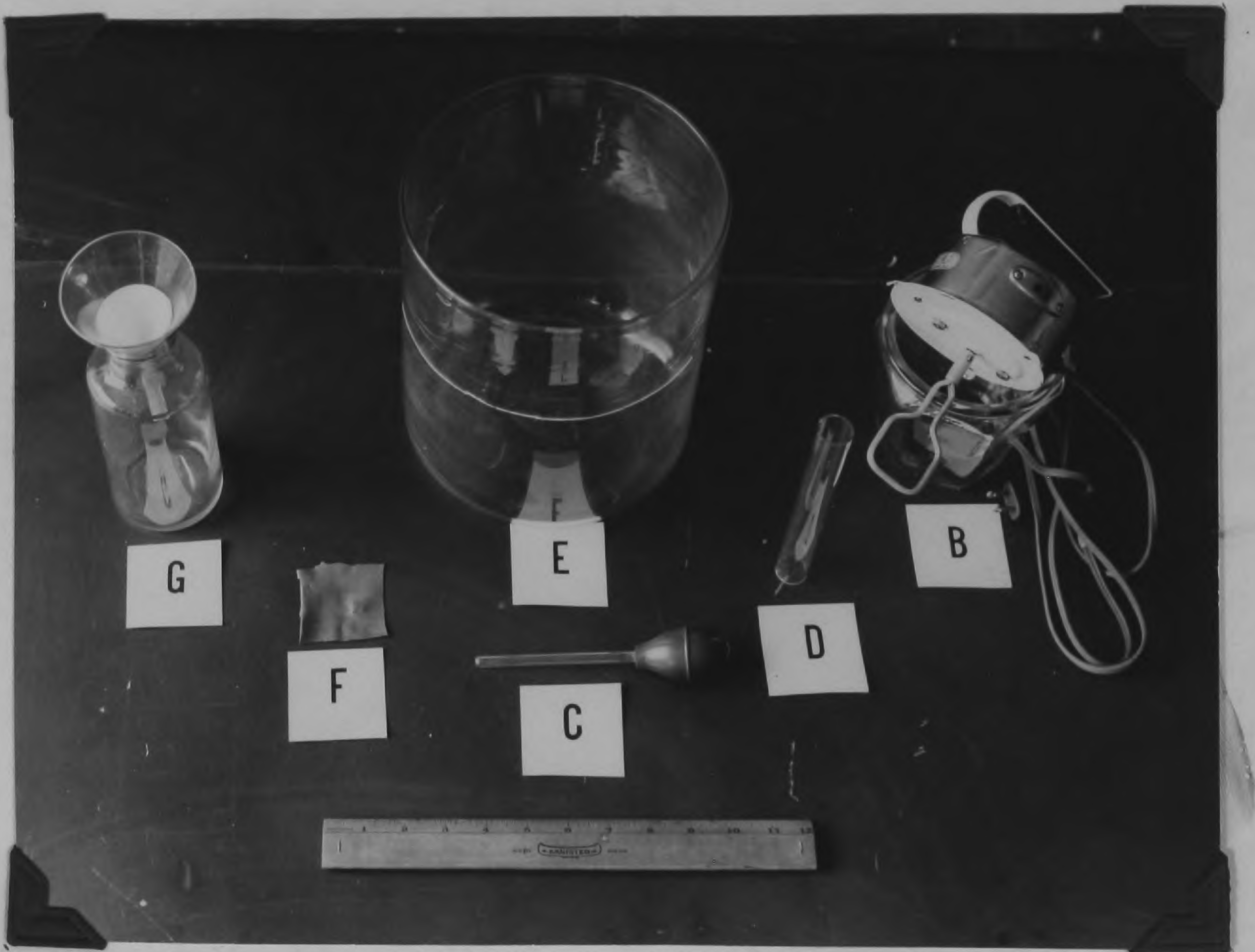


ILLUSTRATION 2. Top View of the Equipment Used in the Analysis of Fecal Samples.

in decreasing amounts. Most of the fecal matter lay close to, or was suspended near, the bottom of the jar. Small particles of fecal matter were also dispersed throughout the liquid, giving it a cloudy appearance. The egg shells remained on the bottom of the jar.

The glass tube, previously described, was then inserted down through the mixture until the end rested on the bottom of the jar. By inserting the small piece of rubber sheeting under the end of the tube and holding it there with one hand and clasping the thumb of the other hand over the opposite end of the tube, a sample section of the material in the jar could be taken out. The total volume of the liquid in the tube was computed to be forty cubic centimeters. Since the total volume of the liquid was four thousand centimeters, a sample of one-hundreth of the total was obtained.*

One sample was removed from each mixture in the battery jar. Fecal matter deposited on the rubber sheeting inside of the sampling tube was allowed to run out of the tube by shifting the sheeting slightly. Hair and feathers remaining were run into a filter paper and allowed to drain. Any material clinging to the inside of the tube was washed into the paper by applying a stream of water from a syringe. Each fecal sample was reduced to a constant weight by drying. Allowance was made for the filter paper by deducting the constant weight of each sheet previously computed.

*A sample of any percent would have given satisfactory results. Relative amounts in each scat would have served the purpose equally as well as absolute amounts.

Pellets

The analysis of pellets was made by separating bones from the surrounding matrix of hair or feathers and weighing each. Pellets previously soaked were easily broken up by the electric egg beater.

In diluting this mixture in a battery jar containing approximately six thousand cubic centimeters of water, a large amount of the bone particles fell to the bottom.

The hair or feathers were than decanted from the bones and drained through a soil sieve with an eight thousandths of an inch mesh. Any bone fragements remaining entangled were separated from the hair or feathers with the aid of a forceps.

In the case of pellets, the total amount of bones and feathers or hair was determined by first air drying to reduce excess moisture and then drying to a constant weight in an oven.

Egg Shells

Egg shells were separated from other fecal material much in the same manner that bones were separated from hair or feathers in the pellets. By carefully decanting, straining through the soil seive and seaprating with a forceps, the amount of egg shells in each sample was obtained and weighed. Weighing took place after drying to a constant weight in this case also.

RETENTION IN SOME MAMMALIAN PREDATORS

The following discussion is based upon the limited amount of material studied.

Graphs numbered I to VIII, inclusive, show the amount of hair and feathers egested progressively from time to time throughout any one feeding series. Each dot represents the analysis percent, by weight, of a separate scat. This percentage was obtained by totaling the analysis figures of all scats in a single series and using this figure as one-hundred percent.

The weight of the hair, feathers or egg shells of each scat was compared to the total weight of these materials in the scats of the series and a percentage computed for each. Each dot is plotted on a percentage scale as the ordinate, and time, in hours as the abscissa. The smooth curve drawn on each graph is an average of the individual curves representing each feeding series and not merely an average of the various points plotted.

Tables 1 to 8 give a tabular record of each feeding, including: Species fed, total weight of hair and feathers in each series, the time and scat at which the peak of each individual curve is reached, together with percentage of hair and feathers represented in this defecation, the total time of retention, the number of the last scat containing hair or feathers after each feeding and the identification number of each individual animal used.

Retention by the Opossum

Fur and Feathers Graphs numbered I and II (pp. 17, 18), respectively, show the amounts of hair and feathers progressively egested by the opossum. The curves representing the average of the feeding series in each case are much alike in many respects -- each rising to a climax of slightly more than thirty percent and declining to zero percent after approximately one-hundred and forty hours of retention. However, certain differences are in evidence. Curve number two, it will be noted, rises more abruptly than curve number one, reaching the peak of egestion in forty hours as compared to a peak at fifty hours in curve one. From this point, the descent in curve two is more sustained than in curve one showing that after the peak of excretion of feathers is reached, larger percentages are found in the remaining scats of the feeding series than are found in the remaining scats of the hair curve.

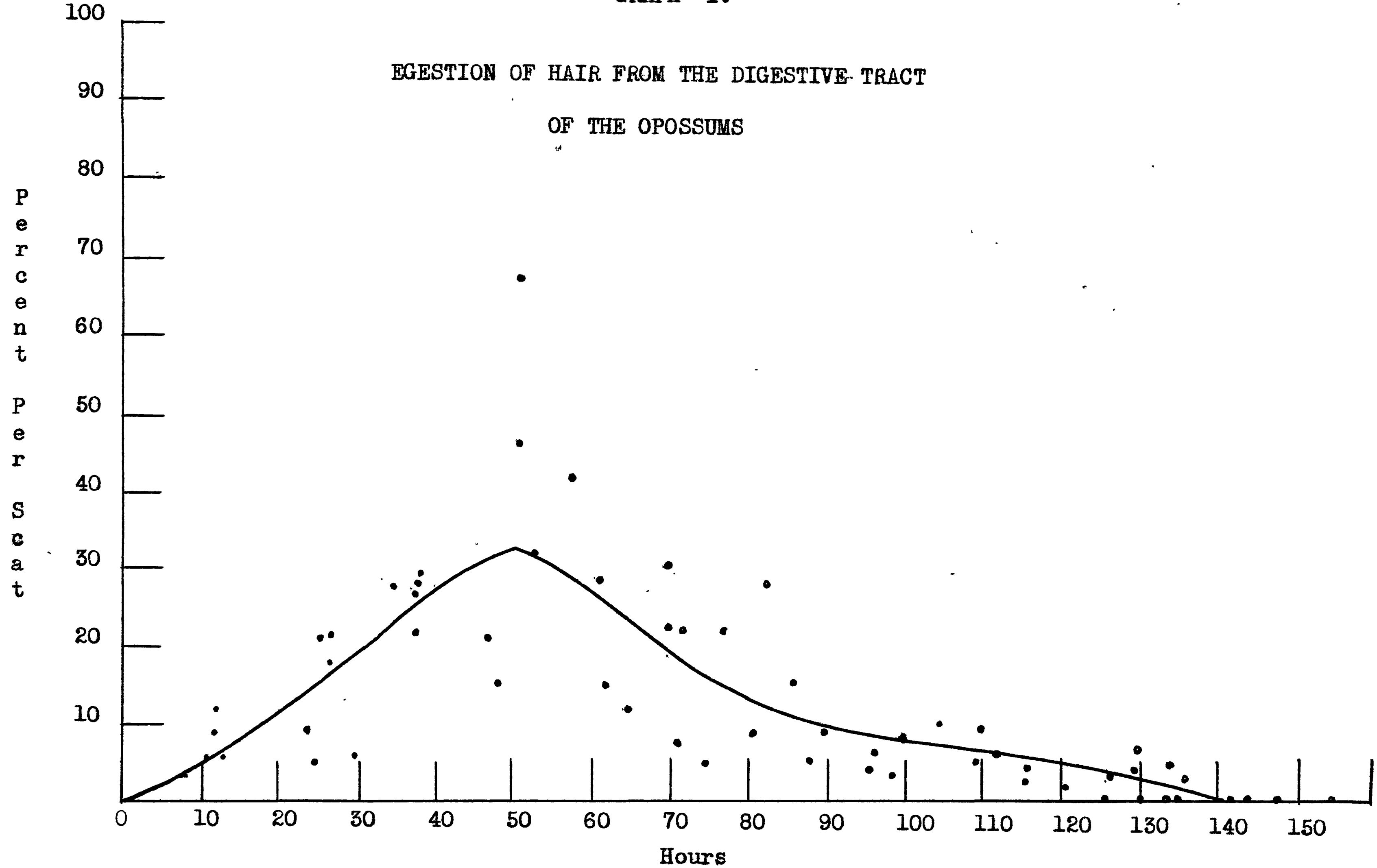
Tables 1 and 2 (pp. 19, 20) show that the similarities of the curves discussed above also occur when considering the two types of feedings on a scat basis rather than time basis.

Egg Shells The average curve for the defecation of egg shells by the opossum on Graph III (pp. 21) shows a retention of egg shells up to a period of one-hundred and sixty hours, which is considerably longer than the retention of either hair or feathers. In general, the curve for the excretion of egg shells is more spread out, the climax being reached somewhere between 65 and 70 hours and carrying twenty-nine percent of the total weight. The

GRAPH I.

EGESTION OF HAIR FROM THE DIGESTIVE TRACT

OF THE OPOSSUMS



GRAPH II.

EGESTION OF FEATHERS FROM THE DIGESTIVE TRACTS OF TWO OPOSSUMS

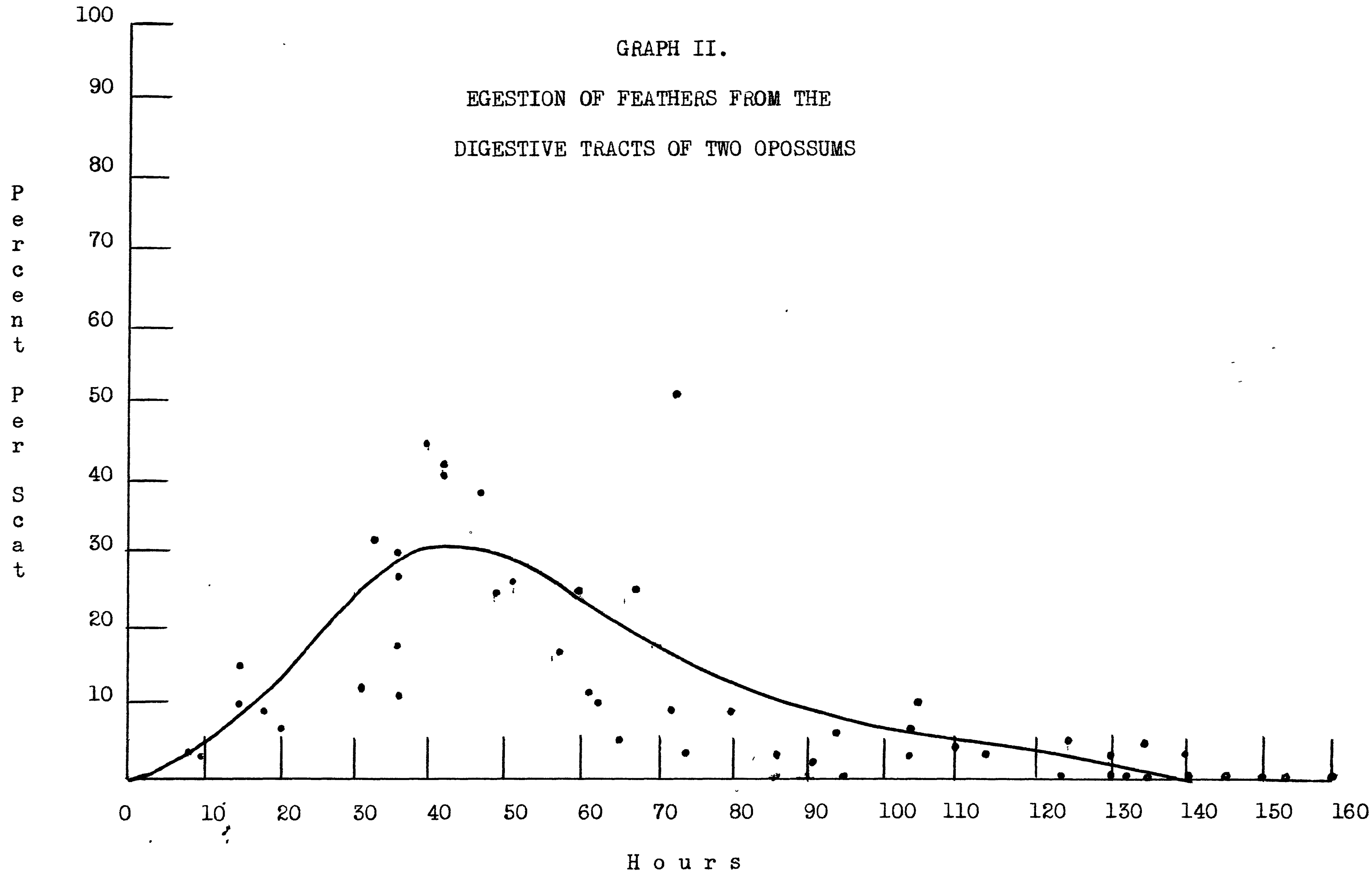


Table 1.

HAIR FEEDINGS TO THE OPOSSUMS

NO.	SPECIES FED	TOTAL WT.	PEAK			TOTAL TIME OF RETENTION		LETTER
			Time	Scat	Percent	Time	Scat	
1	House Mouse (3)	4.8	51	3	67	126	7	O
2	" " (3)	4.0	57	3	42	130	7	O
3	" " (3)	4.6	51	2	46	134	5	K
4	White Footed Mouse (6)	10.1	53	3	32	144	6	K
5	" " " (2)	6.1	61	4	29	131	6	O
6	" " " (9)	16.2	70	3	30	155	7	O
7	Common Rat (1)	3.2	35	2	28	148	7	O
8	Red Squirrel (1)	8.7	37	2	29	130	7	K
	Total	57.7	41	22	303	1118	52	
	Average	7.2	52	2.7	41	147	6.5	

Table 2.

FEATHER FEEDINGS TO THE OPOSSUMS

NO.	SPECIES FED	TOT. WT.	PEAK			TOTAL TIME OF RETENTION		LETTER
			Hours	Scat	Percent	Hours	Scat	
1	English Sparrow (2)	4.7	33	2	32	130	5	O
2	" " (2)	4.3	73	4	51	160	7	O
3	" " (3)	6.3	42	3	42	152	6	K
4	Starling (1)	10.8	47	3	38	140	9	O
5	" (1)	9.7	42	3	41	145	7	K
6	Downy Woodpecker(1)	5.5	40	2	45	135	5	O
	Total	41.3	277	17	249	862	39	
	Average	6.9	46	2.8	41	124	6.5	

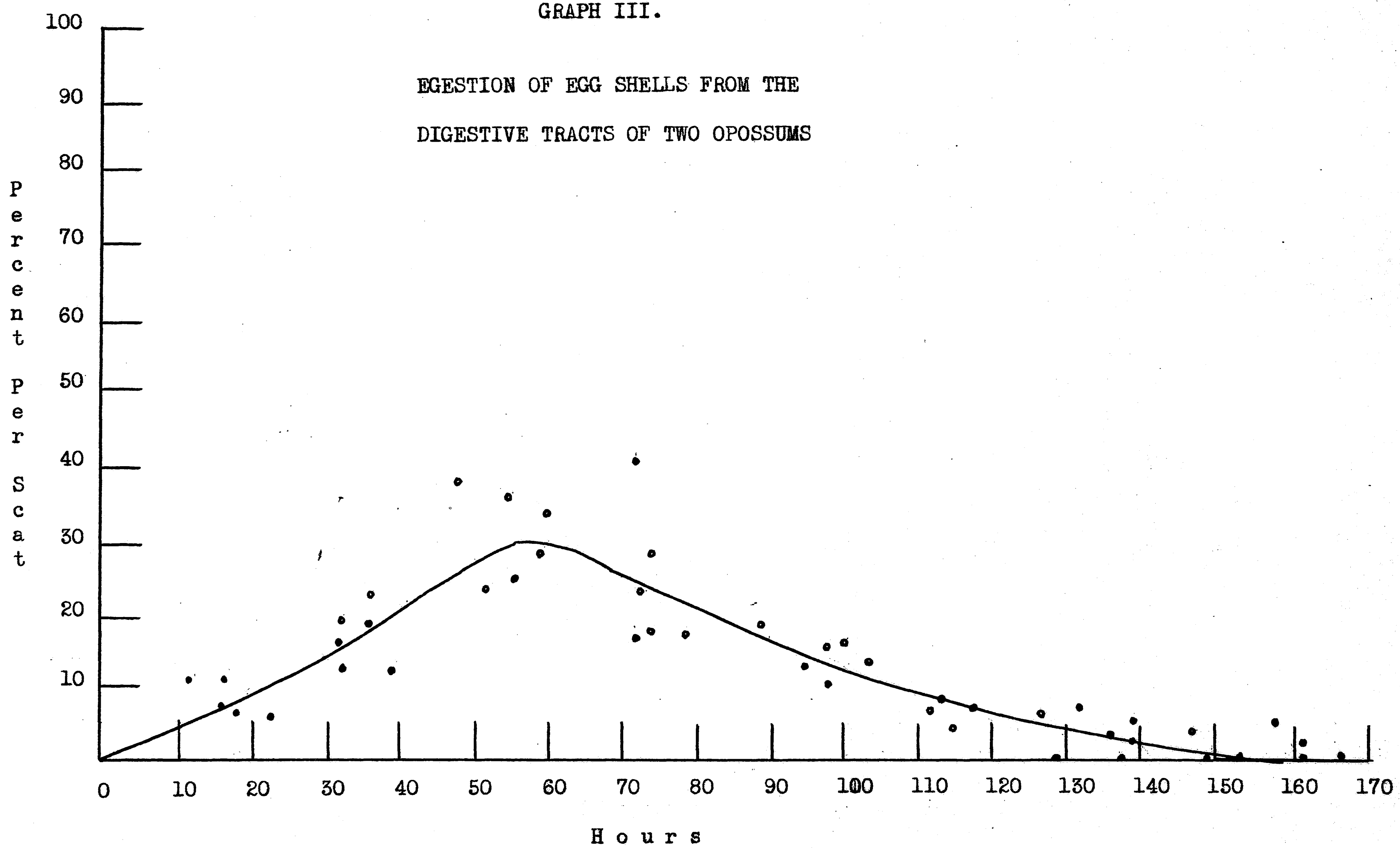
Table 3.

FEEDINGS OF EGG SHELLS TO THE OPOSSUMS

NO.	TOT. WT.	PEAK			TOTAL TIME OF RETENTION		LETTER
		Hours	Scat	Percent	Hours	Scat	
1	6.5	60	3	33	162	8	O
2	4.1	59	3	28	136	7	O
3	2.2	55	3	35	158	7	O
4	3.4	72	4	40	128	6	O
5	2.2	48	2	38	139	6	K
6	6.1	52	3	23	147	7	K
Total	24.5	346	18	197	870	40	
Average	4.1	5.8	3	3.3	145	6.7	

GRAPH III.

EGESTION OF EGG SHELLS FROM THE DIGESTIVE TRACTS OF TWO OPOSSUMS



curves for feathers and hair have a higher climax in percent of weight and reach the peak in a shorter period of time.

From the smooth curves for the excretion of hair, feathers and egg shells in the opossum, it may be concluded that on the average, hair and feathers are retained for almost equal periods of time, although the bulk of feathers passes through the digestive tract slightly sooner than does the hair. Egg shells are not only retained considerably longer, but the bulk of the egg shells are usually egested much later.

Retention By The Skunk

<u>Feathers</u> Graph IV (pp. 23) is a graphical presentation of retention of feathers in the digestive tract of the skunk plotted in the same manner and on the same absicca and ordinate as graphs for the opossum. Unfortunately both skunks refused hair in all forms of feeding attempted. Data of retention of hair must therefore necessarily be omitted.

Graph IV has the appearance of a normal curve, the apex being reached at forty-five hours and forty-three percent, and descending to a total of ninety-hours with the same rapidity with which it rises to the peak. A distribution of this sort gives the indication that the scat representing the middle of the distribution for any feeding series will, on an average, carry the highest percent of feathers. By referring to Table 4 (pp. 24), GRAPH IV.

EGESTION OF FEATHERS FROM THE DIGESTIVE TRACTS OF TWO SKUNKS

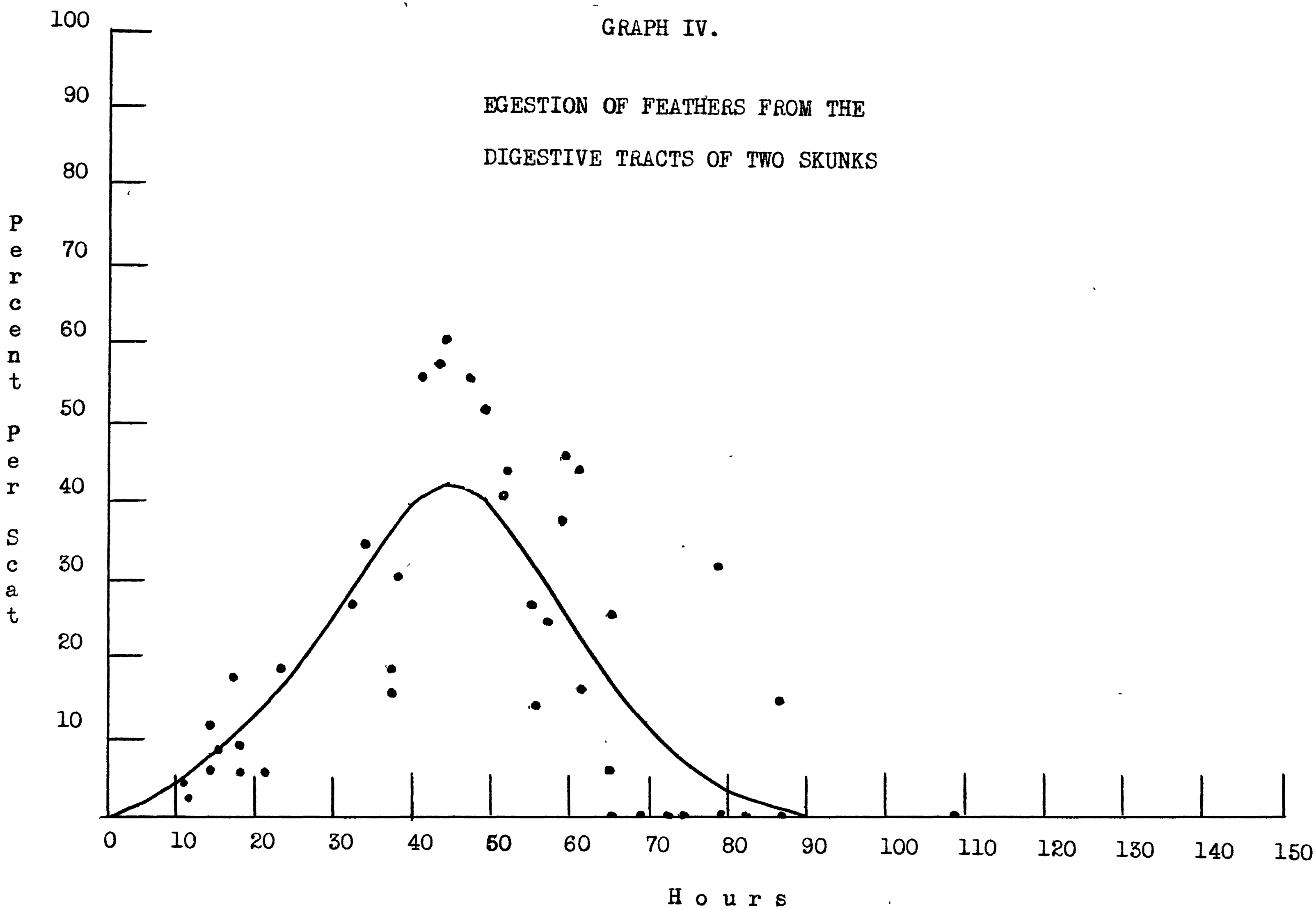


Table 4.

FEATHER FEEDINGS TO THE SKUNKS

NO.	SPECIES FED	TOT. WT.	PEAK			TOTAL TIME OF RETENTION		LETTER
			Time*	Scat	Percent	Time*	Scat	
1	Pheasant Carcass	4.2	61	3	44	86	4	S
2	Pheasant Legs (2)	4.0	49	2	58	68	4	D
3	English Sparrows (2)	1.2	41	2	56	55	3	D
4	" " (2)	3.1	49	3	61	57	4	S
5	" " (2)	1.5	47	2	56	59	3	S
6	Mourning Dove (1)	3.3	52	3	44	61	4	S
7	Chicken Carcass	4.6	59	3	52	79	4	S
8	" "	3.2	51	3	41	65	4	D
9	Starling (1)	1.7	43	2	46	58	4	S
	Total	26.8	452	23	458	588	34	
	Average	3.0	50	2.6	51	65	3.8	

*Time is recorded in hours.

which is a tabular summary of the nine individual feedings of feathers to two individuals, it is shown that the scat containing the largest majority of feathers in five cases out of nine is the third scat in that respective feeding. Scat number three was the peak scat in the four remaining cases.

Table 4 (pp. 24) also indicates that an early rise to the peak does not necessarily mean an early cessation of feathers in the scats of any one series. Entries numbers two, three, five and nine all show an early rise to the peak, however, cases three and four are the only instances in which feathers failed to appear in below average amounts, or after the third scat.

From the tabulated percentage of feathers in the peak scats, an indication of high percentage of feathers in peak scats of below average retention value is shown.

Egg Shells

Graph V (pp 26) shows the egestion of egg shells by the skunk. A comparison of Graph IV and V shows certain similarities, both of which approach the outline of a normal curve. The apex of each coincides at about forty-three percent of the total weight. On a time basis, the scat containing the greatest amount of egg shells is excreted slightly sooner. The average total time of retention is much the same in each.

In the case of feathers, the peak scat average for egestion of feathers is 2.6 (Table 5, pp. 27). This figure was computed by

GRAPH V.

EGESTION OF EGG SHELLS FROM THE DIGESTIVE TRACTS OF TWO SKUNKS

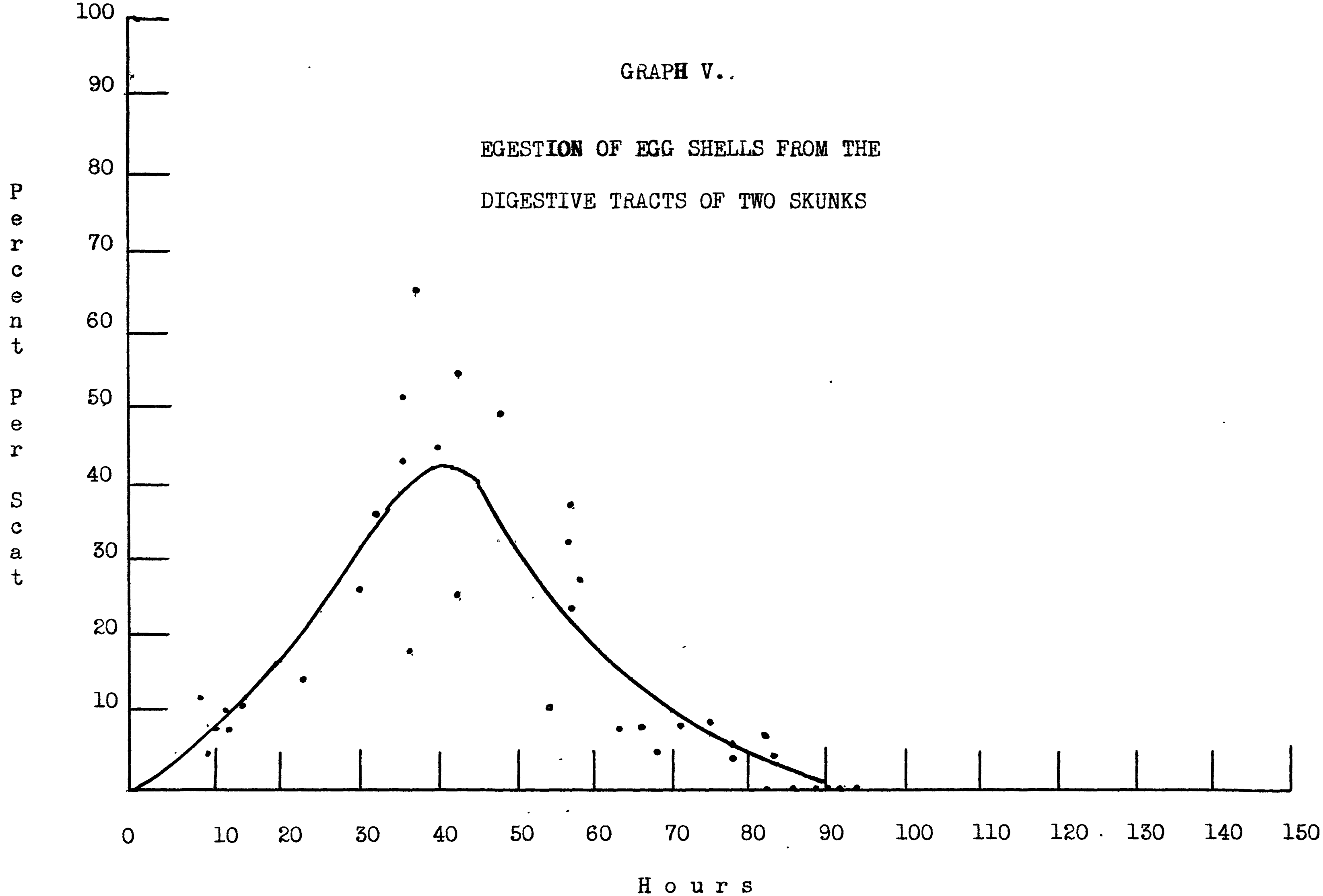


Table 5.

FEEDINGS OF EGG SHELLS TO THE SKUNKS

NO.		TOT. WT.	PEAK			TOTAL TIME OF RETENTION		LETTERS
			Hours	Scat	Percent	Hours	Scat	
1		3.1	49	3	49	83	6	S
2		2.5	36	2	51	79	5	S
3		3.2	38	2	65	77	5	S
4		1.2	36	2	43	84	5	S
5		3.5	43	3	54	83	5	D
6		4.2	41	3	44	76	5	D
Total		17.7	243	15	306	482	31	
Average		2.8	41	2.5	51	80	5	

averaging the total of nine feedings. The peak scat average for egg shells was 2.5 (Table 5). The total average length of retention is 3.8 scats for feather feedings and 5.0 scats for egg shell feedings (Tables 4 and 5).

Retention By The Raccoon

Fur and Feathers — Graph VI (pp. 29) and VII (pp. 30) present the progressive egestion of hair and feathers, respectively, from three raccoons. Both curves rise abruptly to the apex, although the rise in the curve for feathers is less abrupt than that of hair. The peak of the curve for hair comes at about twenty hours, that for feathers occurs at thirty hours.

The fact that the apex of thehair curve occurs at fifty-eight percent while for feathers it is at forty-seven percent indicates that the scat carrying the largest percent of hair in each hair feeding probably, on the average, carries a slightly greater percent of hair than does the corresponding scat for feathers.

In spite of the relatively early and high peak for hair, as compared to feathers, the time of retention is no longer. Both curves meet the abscissa at about sixty hours. Tables 6 (pp. 31) and 7 (pp. 32) list the various feedings of hair and feathers and give the scat number in which the peak and total length of retention are reached in each feeding series.

<u>Egg Shells</u> The average curve for the egestion of egg shells (Graph VIII, pp. 33) is quite different from those of hair and feathers in the raccoon. The peak of egestion is not only more acute, but it comes sooner. Both the ascent and descent are more rapid. In comparing averages, egg shells pass through the digestive tract about ten hours sooner than does hair or feathers.

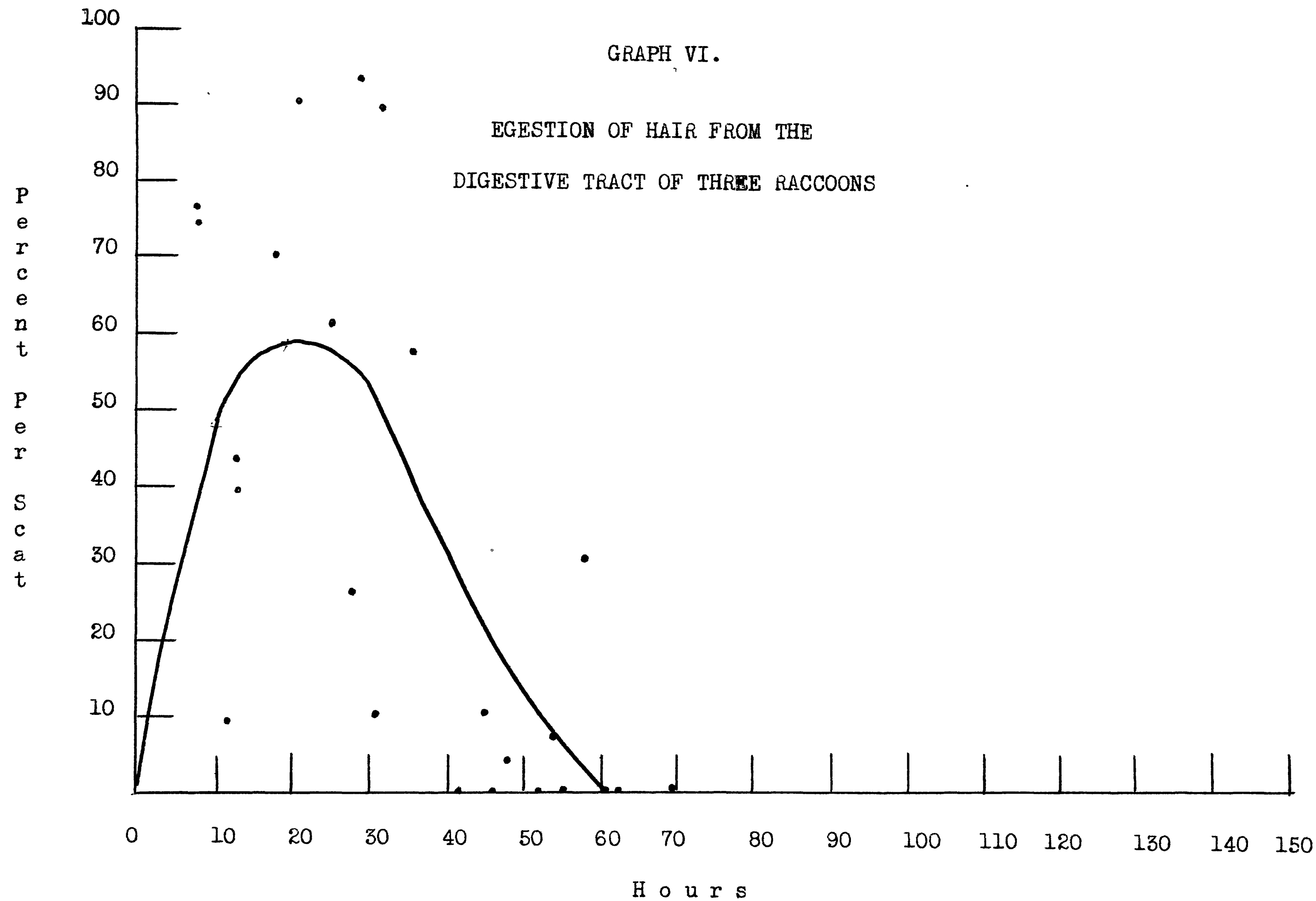
From the average curves, it is indicated that retention for hair and feathers is somewhat alike in the raccoon but that retention for egg shells differs considerably, having a sharper apex, a steeper ascent and descent, and a shorter retention period.

Table 8 (pp. 32) shows that the peak of egestion for egg shells on a scat basis also comes slightly sooner than in hair or feathers feedings. However, the scat average per total length

GRAPH VI.

EGESTION OF HAIR FROM THE

DIGESTIVE TRACT OF THREE RACCOONS



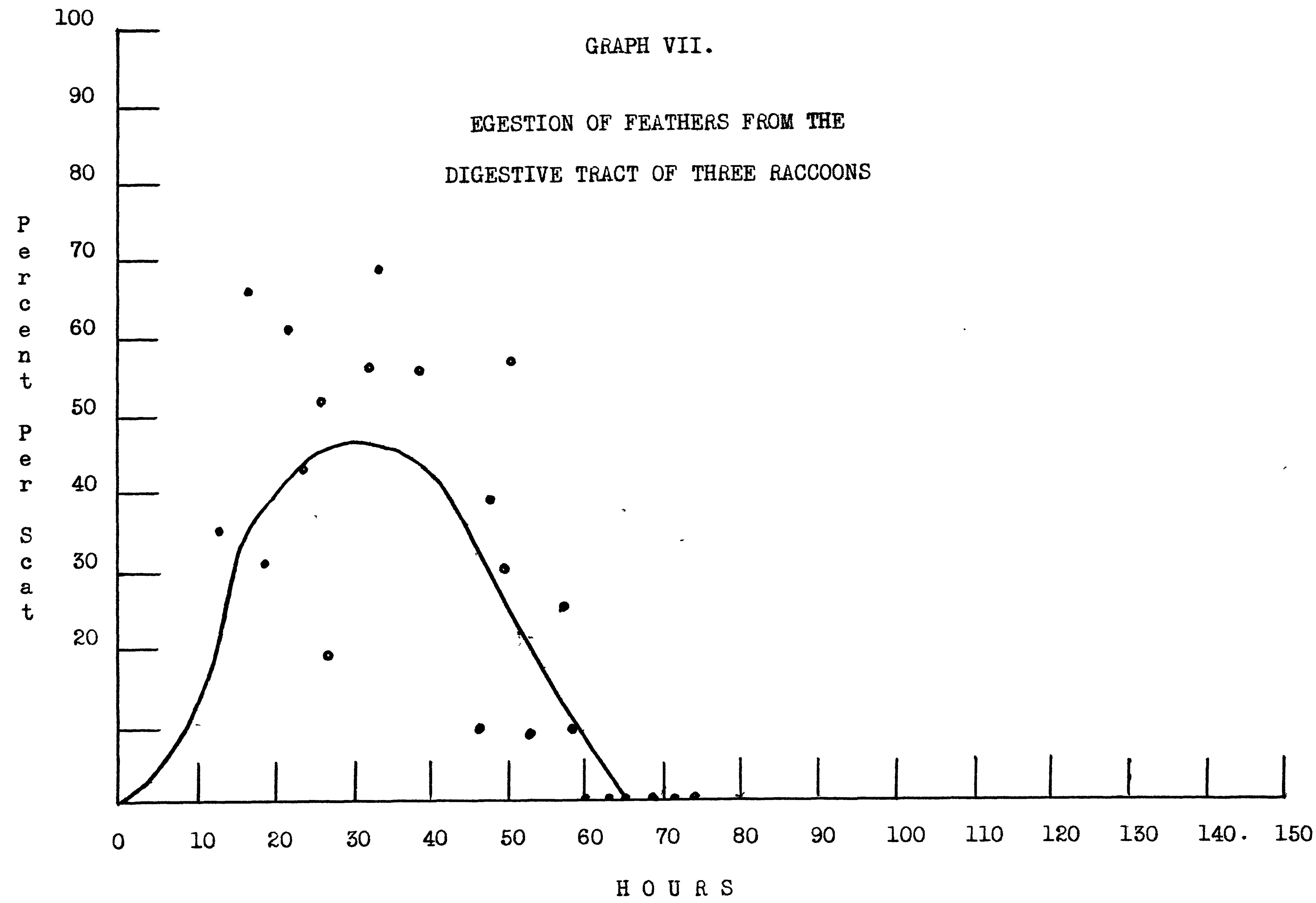

GRAPH VII.
EGESTION OF FEATHERS FROM THE
DIGESTIVE TRACT OF THREE RACCOONS
Percent Per Scat
100
90
80
70
60
50
40
30
20
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140.
150
HOURS

Table 6.

	FEEDINGS OF HAIR TO THE RACCOON							
NO.	SPECIES FED	TOT. WT.	PEAK			TOTAL TIME OF RETENTION		LETTER
			Hours	Scat	Percent	Hours	Scat	
1	Cottontail Rabbit (1)	3.4	8	1	74	31	2	A
2	House Mouse (2)	3.0	37	2	87	48	3	A
3	" " (1)	7.2	29	1	93	64	2	A
4	Common Rat (1)	2.5	28	1	76	31	2	A
5	" " (1)	5.8	21	1	67	41	2	H
6	" " (1)	8.4	18	1	70	58	2	H
7	" " (1)	5.3	25	2	61	25	2	E
8	Red Squirrel (1)	22.4	36	2	57	36	3	H
	Total	58.0	202	11	585	334	18	
	Average	7.2	25	1.4	73	42	23	

Table 7.

FEEDINGS OF FEATHERS TO THE RACCOON

NO.	SPECIES FED	TOT. WT.	PEAK			TOTAL TIME OF RETENTION		LETTER
			Hours	Scat	Percent	Hours	Scat	
1	Pheasant Legs (2)	14.4	32	2	56	46	3	A
2	Pheasant Carcass	4.1	51	2	57	51	2	A
3	English Sparrow(3)	7.5	26	1	56	58	3	H
4	Starling (1)	2.5	22	1	61	50	2	E
5	" (2)	8.3	38	2	69	38	2	A
6	English Sparrow(3)	5.1	39	2	56	57	3	H
7	" " (2)	3.2	17	1	66	53	3	A
	Total	45.1	225	11	421	353	18	
	Average	6.4	32	1.6	60	50	2.6	

Table 8.

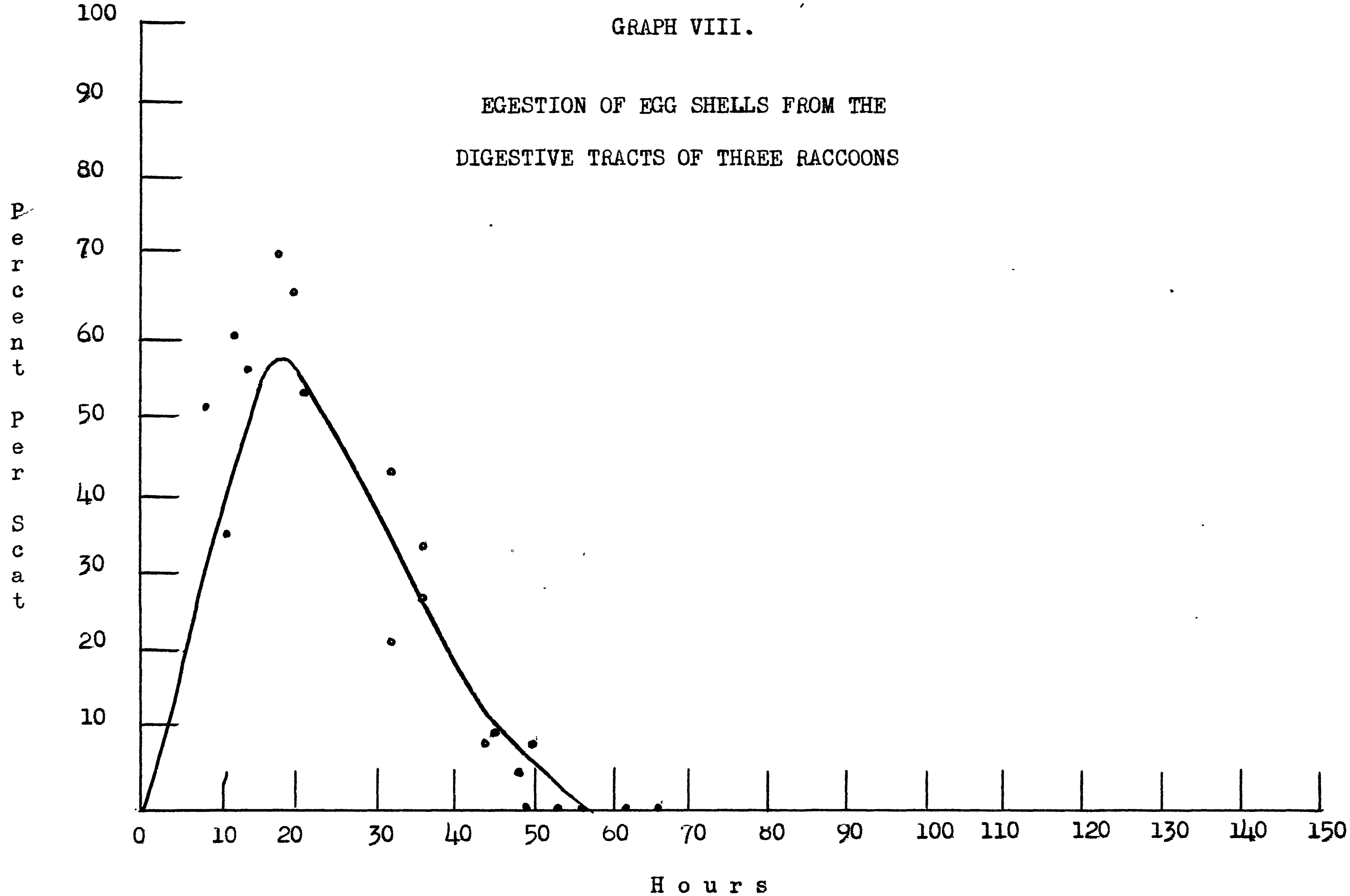
FEEDINGS OF EGG SHELLS TO THE RACCOON

NO.		TOT. WT.	PEAK			TOTAL TIME OF RETENTION		LETTER
			Hours	Scat	Percent	Hours	Scat	
1		9.8	12	1	61	48	3	A
2		5.4	14	1	57	50	3	A
3		7.2	20	1	67	44	3	A
4		3.2	11	2	36	45	3	H
5		4.6	18	1	72	36	2	H
Total		30.2	75	6	293	223	14	
Average		6.0	15	1.2	59	45	2.8	

GRAPH VIII.

EGESTION OF EGG SHELLS FROM THE

DIGESTIVE TRACTS OF THREE RACCOONS



of retention is slightly higher than hair or feathers.

Summary of Retention in Mammalian Predators

As a summation of retention in the various mammalian predators studied, it can generally be agreed upon, from the tables and graphs, that retention is longest in the opossum, shortest in the raccoon and is mid-way between these two in the skunk. This fact is also evident in Table 9 (pp. 35) which gives an average of time and scats for the retention of each predator.

The same order of succession, from long retention to short retention -- opossum, skunk and raccoon -- follows when considering the time at which the scat bearing the greatest amount of hair or feathers appears in each feeding series. The opossum has the longest period of retention before the defecation of the peak scat, the skunk next and the raccoon last.

In comparing the length of retention of the three materials fed -- hair, feathers and egg shells -- Table 9 indicates that egg shells have the greatest retention on a scat basis in all species studied. This is not true in all cases when considering retention on an hour basis. No marked general difference can be noted between hair and feathers.

Table 9.

SUMMATION OF EGESTION IN MAMMALIAN PREDATORS

PREDATOR	FEEDING	TABLE NO.	PEAK		TOTAL	
			Av. Hours	Av. Scat	Av. Hours	Av. Scat
Opossum	Hair	1	52	2.7	147	6.5
"	Feathers	2	45	2.8	119	6.5
"	Egg Shells	3	58	3.0	145	6.7
Skunk	Feathers	4	50	2.6	65	3.8
"	Egg Shells	5	41	2.5	80	5.2
Raccoon	Hair	6	26	1.4	42	2.1
"	Feathers	7	32	1.6	50	2.6
"	Egg Shells	8	15	1.2	45	2.8

INTRA-SPECIFIC DIFFERENCES OF RETENTION

Differences in retention are not limited solely to different species. Various feedings of the same species show some variation. This may be readily seen by referring to any of the graphs giving the record of egestion for the different feedings, and noting the distribution of the points plotted for the various feeding series.

From a study of the data at hand, it is evident that certain indications of some factors that may be suspected as influences are shown to have no well defined affect upon retention. Among these are the effect of different kinds of hair and feathers eaten, variation between different individuals of the same species and the amount of hair, feathers or egg shells ingested.

A comparison of the figures of Tables 1 to 8, inclusive, show that there is no indication of correlation between descrepencies in the distribution of the individual curves and differences in retention of types of feathers and hair eaten. This is also true when considering the amount of food eaten. Variation of retention among the individuals of each species used is also evident in the tables. Whether or not this variation is distinct for that individual cannot be stated.

Certain other conditions have a definite affect upon retention. These are: The amount and quality of food taken before and after each feeding of hair, feathers or egg shells, daily and

and periodic activity of the animal, which in turn may be affected by meterological conditions, season of the year, or individual variations and any difference in digestive function over a long period of time, or during the time the meal fed is passing through the digestive tract.

Several experiments concerning the effect of the amount of food upon retention may be cited as an illustration of the effect of amount of food taken after each initial feeding. In feedings of hair and feathers to an opossum followed by a period of three to five days in which no food was given, it was found that egestion of hair or feathers was complete in two and sometimes three scats. The feces on these occasions were small and hard, consisting almost entirely of hair or feathers. The effect of conditions, in which the animal was given more food than it could eat, was not determined.

As no records of activity were kept during the course of the experiments, the effect of activity upon retention was not ascertained. However, the effect of activity upon digestion is well illustrated in studies made upon the effect of exercise in stimulating human digestion. Lack of activity has in many cases caused constipation and general interruptions of the digestive process (Alvarez, 1928).

Digestive functions in the higher animals may vary considerably over short periods of time. This is undoubtedly due to variation in the secretion of digestive juices and in movement of food along the intestines (Alvarez, 1924).

From the above remarks, it is quite evident that variation of retention in a single species cannot definitely be attributed to any one factor. All in all, it appears that retention variability intra-specifically is undoubtedly the sum total of many factors, each of which contributed more or less to the discrepancies observed.

DIGESTION IN MAMMALS
IN RELATION TO RETENTION

The term feces is applied to waste matter voided from the bowel by the action of defecation. Feces are composed of several constituents such as water, undigested material, of which hair, feathers and egg shells are a part in predatory mammals, indigested food particles, remains of digestive secretions, desquamated epithelial cells, numerous bateria, inorganic salts, and other minor substances (Dukes, 1935, pp. 298).

Since hair, feathers, egg shells and other undigestible material ingested must eventually be egested in the feces, the rate at which feces are defecated affects retention. Digestion systems vary within the different species of animals not only in anatomical structure, but in digestive functions as well.

The definite differences in retention in the opossum, skunk and raccoon should find a partial explanation, at least, in these differences in anatomy and physiological functions of the digestive tract. Due to a lack of investigation into the comparative anatomy and physiology of digestion in these animals, any discussion in this direction is limited. Certain factors that might possibly exert a difference upon retention can be mentioned.

Size of the Digestive Tract

Any effect size of the digestive tract may have upon retention cannot be stated. Size of the digestive tract varies to some extent among species (Mitchell, 1905) and to a lesser extent between individuals of the same species.

Peristalic Movement

The food mass is moved from place to place in the bowel by peristalic action and other movements of lesser importance in carnivores (Dukes, 1935).

Peristalic movement varies in rate and magnitude between the various species of animals. It also varies in different parts of the small intestine and at different times during the process of digestion. The difference of rate and magnitude between species, which in turn affects rate of movement of food, may probably be one factor contributing to difference in length, and other phenomena of retention.

Size of the Caecum

The caecum in carnivores is small and poorly developed (Mitchell, 1905; Dukes, 1935). In the opossum, it is fairly well developed (Mitchell, 1905).

Among the functions of the caecum in the herbivores, in which it is well developed, is to serve as a reservoir in which cellulose can soak and undergo digestion by bacteria. According to Dukes (1935), movements are usually slow and sluggish in the caecum of most mammals, but may at some times become powerful.

Due to its relatively small size, even in the case of the opossum, the degree to which the caecum may engulf and hold hair, feathers or egg shells is not known. Nevertheless, it may contribute to some extent in causing a hold-over of these materials bringing about a longer period of retention.

Size of the Colon

There is little need for the large intestine in carnivores as far as actual digestion is concerned, digestion being almost entirely completed in the small intestine. Its chief function is a storage place for fecal matter before egestion (Dukes, 1935).

A small amount of peristalic action is found in the upper end of the colon, but on the whole, movement of food as a result of movement of the intestinal wall can be disregarded. For this reason, fecal material before passing out the anus must, for the most part, be forced down to the region of the rectum by the pressure of other food residue above it (Alvarez, 1928, pp. 299). For these reasons it would be quite logical to assume that the size of the large intestine has some affect upon retention since retention depends a great deal upon rate of movement of food through the tract.

Alvarez (1928) found in his studies on human digestive tracts that defecations are materially reduced in number in cases where the colon is long and large in diameter or when the amount of ingested food is reduced.

Size of the Haustra

In an experiment to test the rate at which food moved through the intestine, Alvarez (1928, pp. 276) fed a large number of small beads two millimeters in diameter to several medical students. Different colored beads were given on three consecutive days. Collection and analysis of the stools showed that a definite amount of retention was exercised by the digestive tract. Certain beads of one feeding were passed prior to the total number of beads of a previous feeding until beads of all three colors arrived in one stool. Alvarez attributes this retention to the fact that some of the first set of beads got off into the haustra of the large intestine, out of the central current. Final expulsion of these from the haustra may have made room for part of the beads of the second and third set, thus, intermixing the colors of beads in the scats.

Haustra in the large intestine are not only prevalent in man, but in the carnivores as well. If Alvarez' assumption is true, the haustra may greatly affect retention. No figures as to the relative size and character of the haustra is at hand for the various mammals used in these experiments, but it is quite logical to assume that variation does occur.

RETENTION OF HAIR AND FEATHERS IN PREDATORY BIRDS

In the predatory birds, under observation, retention in relation to food habit studies was found to take on a lesser importance than was the case in mammals. In a few instances all species, other than the barn owls, were found to regurgitate two pellets from a single feeding but these instances were not the usual occurrance. However, in the course of the study of the bird predators, some interesting facts of direct concern to food habits studies were noted.

Retention in the Great Horned Owl

Table 10 (pp. 44) and 11 (pp. 45) show the results of several feedings of both hair and feathers to one great horned owl.

A comparison of retention for hair and feathers indicates that length of retention is almost the same. The average size of pellets collected is slightly higher for feathers. The average weight of the two kinds of pellets collected is about the same. The analysis of pellets for contents of bones and hair or feathers indicates that feather pellets have a lower average weight percent of bones than do hair pellets. This may be due to the relative lightness of bird bones and probably the fact that bird bones are more readily digestible.

Columns four on Tables 10 and 11 tabulate the weight of the pellets compared to the length of retention on a gram-hour

Table 10.

FEEDINGS OF HAIR TO THE GREAT HORNED OWL

NO.	SPECIES FED	HRS. RE-TAINED	TOT. GRAM WT.	HRS. OF RETENTION PER GRAM WT.	BONES		HAIR	
					Gram Wt.	Percent of Tot.	Gram Wt.	Percent of Tot.
1	Cottontail Rabbit (1)	25	11.9	2.1	8.3	69	3.6	31
2	Red Squirrel (1)	27	10.5	2.6	7.9	75	2.6	25
3	Common Rat (2)	21	8.5	2.5	4.9	58	3.6	42
4	" " (2)	28	9.1	3.1	6.0	66	3.1	33
5	" " (1)	26	4.2	6.2	2.9	69	1.3	31
6	House Mouse (6)	19	4.2	4.5	2.5	60	1.7	30
7	Muskrat (1)	24	24.6	9.8	20.9	85	3.7	15
8	(second pellet from 7)	44	6.5	6.8	5.7	88	.8	12
9	Muskrat (1)	23	7.2	3.2	5.2	72	2.0	28
10	Thirteen-Lined Ground Squirrel (2)	32	5.3	6.0	3.9	74	1.4	26
	Total	269	92.0	46.8	68.2	716	23.8	273
	Average	26.9	9.2	4.7	6.8	71.6	2.4	27.3

Table 11.

FEEDINGS OF FEATHERS TO THE GREAT HORNED OWL

NO.	SPECIES FED	HRS. RE-TAINED	TOT. GRAM WT.	HRS. OF RETENTION PER GRAM WT.	BONES		HAIR	
					Gram Wt.	Percent of Tot.	Gram Wt.	Percent of Tot.
1	Pheasant Parts	21	4.4	4.8	2.1	48	2.3	52
2	Crow (1)	24	17.6	13.6	9.1	52	8.5	48
3	English Sparrow (3)	15	14.1	1.6	6.7	47	7.4	52
4	" " (2)	23	4.2	5.5	1.9	45	2.3	55
5	" " (4)	32	16.3	1.9	8.2	51	8.1	49
6	Starling (2)	29	9.9	2.9	5.9	60	4.0	40
7	Pheasant Parts	28	6.1	4.6	2.7	44	3.4	56
	Total	172	72.6	34.9	33.6	347	36.0	353
	Average	2.5	10.4	4.9	4.8	50	5.1	50

basis. From these figures, it is indicated that no correlation between the weight of the pellet and length of retention is evident. A great deal of variation in time of retention is also seen in cases where more than one feeding of each species occurs.

The number of feather pellets collected from the great horned owl were less than hair pellets, although the feather feedings were in the majority. It was found that in some cases pellets were not regurgitated after feather feedings. This failure of regurgitation could not be easily tied up with any particular kind of feathers as it happened after feedings of English sparrows, ruffed grouse and starlings.

Retention of Pellets in the Barn Owl

Data on retention and analysis of pellets obtained from the feeding of two barn owls and tabulated on Tables 12 (pp. 47) and 13 (pp. 48) revealed results much the same as those obtained from the great horned owl.

Hair pellets were retained the same average time as feather pellets. The average weight of the hair pellets is 1.2 grams larger than that of feathers. No correlation between time of regurgitation and weight in grams of pellets, or species fed is evident.

In feedings of the barn owl, no cases of regurgitation of two pellets for a single feeding were recorded.

Table 12.

RETENTION OF HAIR BY THE BARN OWL

NO.	SPECIES FED	HRS. RE-TAINED	TOT. GRAM WT.	HRS. OF RETENTION PER GRAM WT.	BONES		HAIR	
					Gram Wt.	Percent of Tot.	Gram Wt.	Percent of Tot.
1	White Footed Mouse (3)	43	3.3	10.3	1.5	45	1.8	55
2	" " " (5)	31	6.0	5.2	4.3	72	2.7	18
3	" " " (4)	41	4.5	.9	2.3	51	2.2	50
4	House Mouse (8)	24	3.9	6.1	2.3	59	1.6	41
5	" " (7)	18	4.4	4.1	2.8	64	1.6	36
6	Common Rat (1)	36	7.3	4.9	4.8	66	2.5	34
7	" " (1)	26	9.1	2.9	6.7	74	2.4	26
8	" " (1)	30	9.0	3.3	5.4	60	3.6	30
9	House Mouse (6)	29	6.1	4.8	4.1	67	2.0	33
10	" " (6)	32	5.4	5.9	3.7	68	1.7	32
11	" " (5)	19	6.3	3.0	4.8	75	1.5	25
12	" " (2)	26	2.3	1.1	1.6	70	.7	30
13	" " (3)	33	2.9	1.1	1.5	52	1.3	48
14	Cottontail Rabbit (1)	13	2.0	6.5	.4	20	1.6	80
15	" " (1)	21	3.5	6.0	.3	8	3.2	92
	Total	390	76.0	66.1	47.2	871	31.4	630
	Average	27	5.7	4.4	3.1	58	2.1	42

Table 13.

RETENTION OF FEATHERS BY THE BARN OWL

NO.	SPECIES FED	HRS. RE-TAINED	TOT. GRAM WT.	HRS. OF RETENTION PER GRAM WT.	BONES		HAIR	
					Gram Wt.	Percent of Tot.	Gram Wt.	Percent of Tot.
1	English Sparrow (1)	24	3.9	6.1	1.1	28	2.8	72
2	" " (1)	21	3.9	5.4	1.5	39	2.4	61
3	" " (2)	32	5.4	5.9	2.3	43	3.1	57
4	" " (2)	23	4.7	4.9	1.8	38	2.9	62
5	Starling (1)	28	4.7	5.9	2.2	47	2.5	53
6	" (1)	32	4.2	7.6	2.4	57	1.8	43
	Total	160	26.8	35.8	11.3	252	15.5	348
	Average	2.7	4.5	6.0	1.9	42	2.6	58

Retention in the Red-Shouldered Hawk

Retention data for the red-shouldered hawk is confined to pellets collected after hair feedings. No pellets were obtained from any of the feather feedings.

The data on hair, as compiled on Table 14 (pp. 50), shows an average size of the hair pellets in the red-shouldered hawk to be decidedly below that of either of the owls. The contents of bone by percent of total weight, as compared to the percent of total weight of hair, is decidedly less in the hawks than in the owls. (See Graphs IX, X and XI, pp. 51, 52, 53) Computations of the hours of retention per gram weight (Table 4, Column 4) show that in the case of the red-shouldered hawk there is no definite correlation between time of retention and weight of the pellets. Differences between kinds of hair ingested are not evident.

Summation of Retention in Hawks and Owls

In summation of the retention of hair and feather pellets by predatory birds, certain indications may be considered.

Time of retention, on the average is greater for the red-shouldered hawk than it is for either the barn owl or great horned owl while the average weight of pellets is less. Percentages of bones by weight compared to weight of the hair in each pellet is directly the reverse of the same relation in the case of

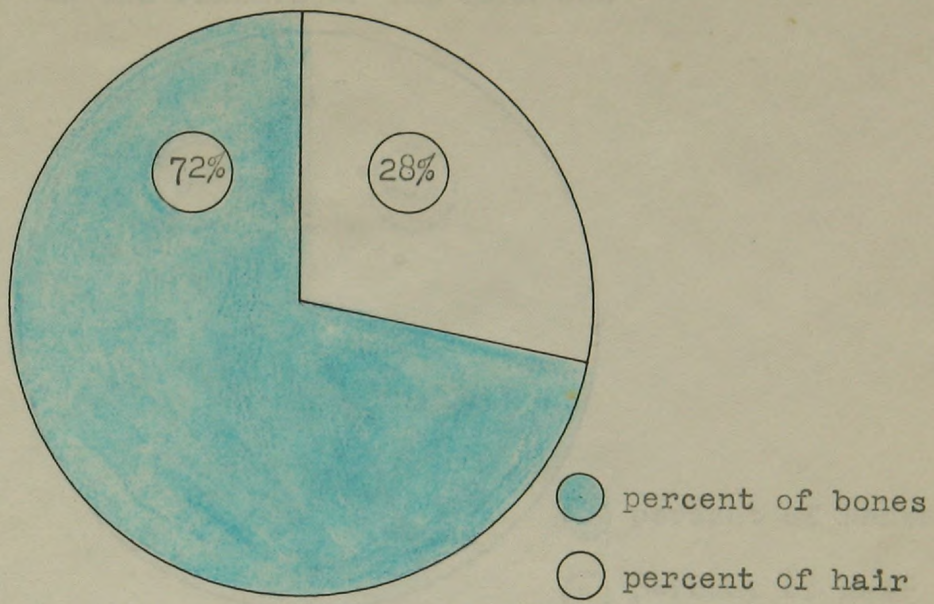
Table 14.

RETENTION OF HAIR BY THE RED-SHOULDERED-HAWK

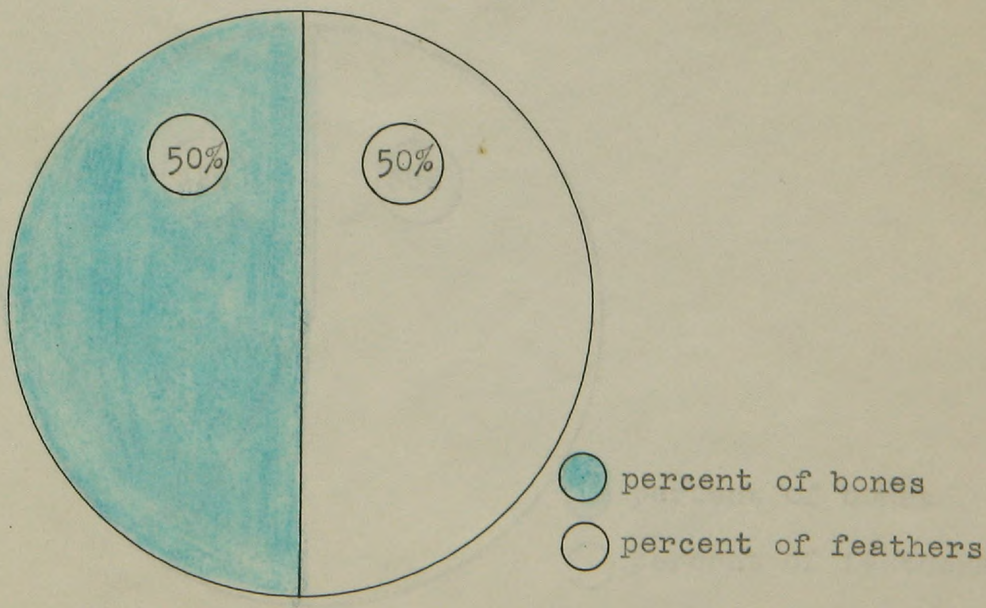
NO.	SPECIES FED	HRS. RE-TAINED	TOT. GRAM WT.	HRS. OF RETENTION PER GRAM WT.	BONES		HAIR	
					Gram Wt.	Percent of Tot.	Gram Wt.	Percent of Tot.
1	White Footed Mouse (2)	24	2.3	10.4	.7	30	1.6	70
2	House Mouse (12)	20	4.3	4.7	.8	19	3.5	81
3	(Second from 2)	44	4.8	9.2	.6	13	4.2	87
4	House Mouse (1)	12	.5	23.1	.1	13	.4	87
5	White Footed Mouse	46	2.4	19.3	.9	37	1.5	63
6	Field Mouse (6)	46	1.6	28.7	.3	19	1.3	81
7	(Second pellet from 6)	49	2.1	23.3	.6	28	1.5	72
8	Common Rat (1)	43	4.6	9.4	.8	17	3.8	83
9	" " (1)	52	6.2	8.4	.9	14	5.3	86
	Total	336	32.8	136.5	6.7	190	27.1	710
	Average	38	3.6	13.6	.9	21	3.0	79

GRAPH IX

WEIGHT PERCENTAGES OF HAIR OR FEATHERS IN THE PELLETS OF THE GREAT HORNED OWL



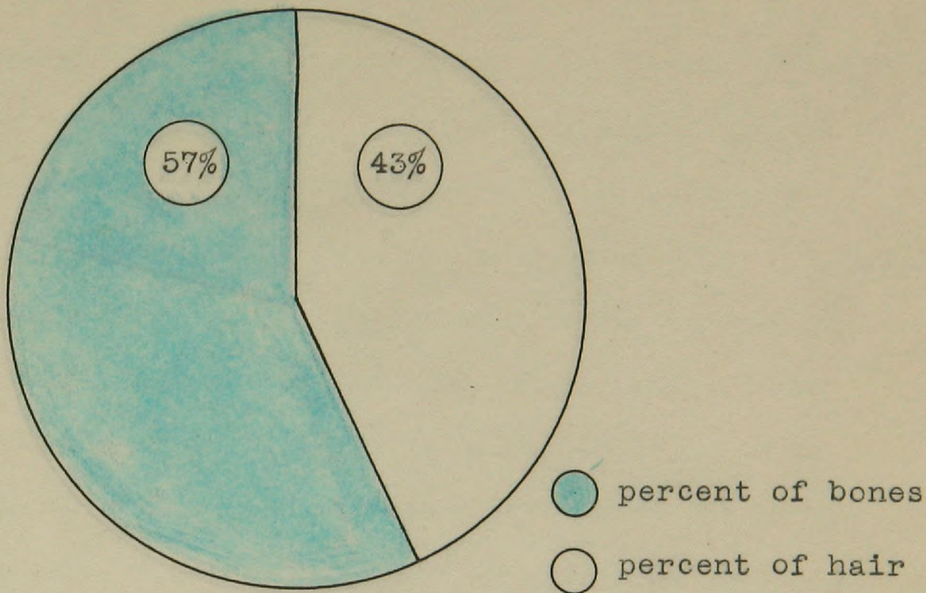
The above graph is based on ten separate feedings of mammals to one great horned owl. The weight of bones in each pellet, expressed on a percentage basis, is considerably greater than the weight of hair.



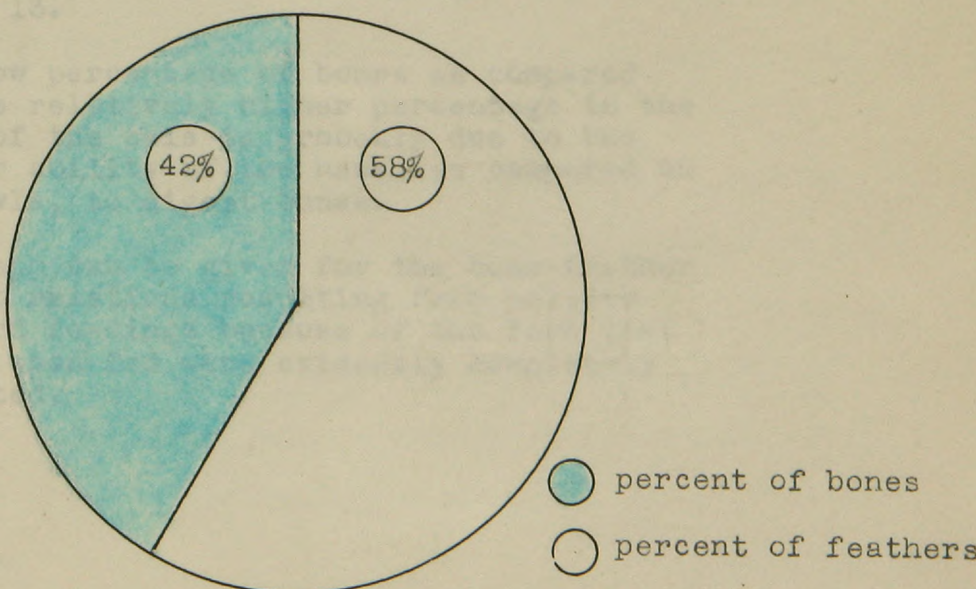
This graph is the result of seven feedings of birds and parts of birds fed to the same great horned owl. The average percentage of bones in each pellet from bird feedings as compared to the average percentage of bones for the mammal feedings is 22% less.

GRAPH X

WEIGHT PERCENTAGES OF HAIR OR FEATHERS
IN THE PELLETS OF THE BARN OWL



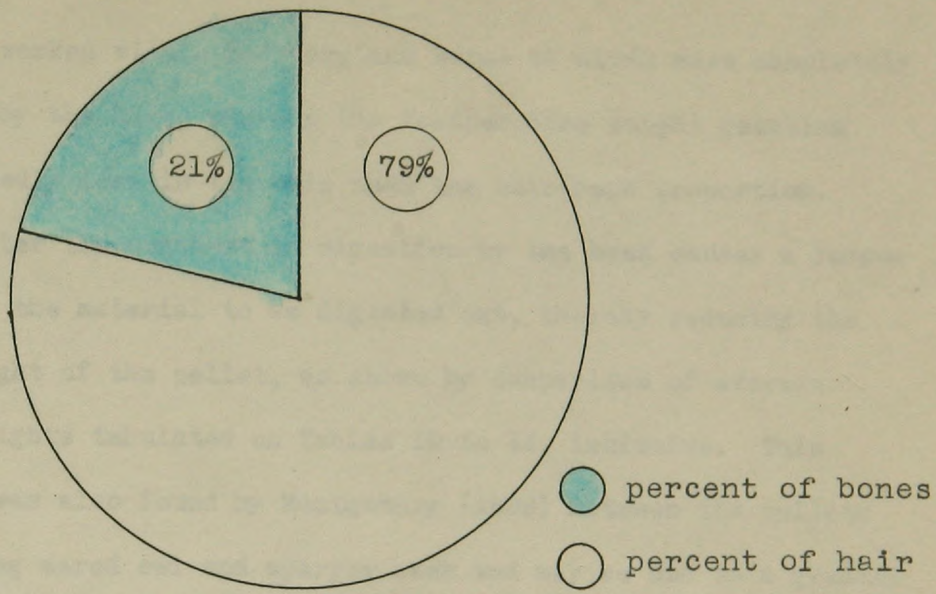
The results of fifteen feedings of mammals to two Barn Owls constitutes the data for the above graph. The percentages are calculated on a weight basis. A list of the mammals fed is included in Table 11.



This graph represents the weight analysis of bones as compared to feathers resulting from pellets obtained from six feedings of birds to two Barn Owls. The low percentage of bird bones as compared to mammal bones in the two kinds of pellets, which is also shown in the preceeding graphs for the Great Horned Owl, is again shown in this graph.

GRAPH XI

WEIGHT PERCENTAGE OF HAIR IN THE PELLETS
OF THE RED SHOULDERED HAWK



This graph results from the analysis of pellets from nine separate feedings of various mammals to one Red Shouldered Hawk. The percentages are based on the average weight of bones and hair. A list of the mammals fed may be found on Table 13.

The low percentage of bones as compared to the relatively higher percentage in the case of the owls is probably due to the better ability of the hawk, as compared to the owls, to digest bones.

No graph can be given for the bone-feather weight relations resulting from pellets of bird feedings because of the fact that birds when fed were evidently completely digested.

the owls worked with. Feathers and bones of birds were completely digested by the hawk, whereas the feather-bone weight relation was decidedly less in the owls than the hair-bone proportion. This greater thoroughness in digestion by the hawk causes a larger amount of the material to be digested out, thereby reducing the total weight of the pellet, as shown by comparison of average pellet weights tabulated on Tables 10 to 14, inclusive. This relation was also found by Montgomery (1899) between the pellets of the long eared owl and sparrow hawk and may be due to a greater amount of free and total acidity in the stomach of the hawks.

The total absence of pellets from bird feedings in hawks is undoubtedly due to the fact that bird bones are completely digested. Pellets are usually formed around bones. (See Hibbert-Ware, 1928) Whether or not feathers are easier to digest than hair, and for that reason are not regurgitated in pellets lacking bones, is in question.

Certain experiments conducted on the great horned owl also indicate, although not definitely, that bones in the digestive tract are necessary before pellets will be regurgitated. Although the great horned owl in many cases did not disgorge pellets in which bones were included with the feeding of feathers, no pellets were formed in any of the feedings of feathers alone.

DIGESTION IN HAWKS AND OWLS
IN RELATION TO PELLET FORMATION

Observations have been made of movements of the stomach in the act of digestion in owls but not in hawks, however, similarity of movement in the stomach of pellet forming species is quite logical to assume. Reed (1925) observed this action through the use of a flouriscope. Material fed was rolled in barium compounds making it quite easy to trace the course of the food within the animal. From these experiments, it was found that the capacity of the stomach for holding food was tremendous, the organ enlarging greatly with ingestion. The opening of the pyloric valve, as seen through the flouriscope and measured in autopsies was found to be no larger than one millimeter in diameter and was placed very close to the cardiac opening in the upper end of the stomach. Peristalic action, although sluggish, was fairly constant, producing a slow flow of partially digestive material through the pyloric opening. The size of this opening produced a mechanical bar to anything but finely divided material from the stomach to the intestine.

In spite of the fact that the mixing of digestive fluids with the stomach contents was found to be slow and sluggish, all pellets examined in both hawks and owls appeared to be well digested. No putrification occurred after collection when the pellets were allowed to stand in the open for long periods of time. Examination showed that no digestible material remained after ejection. However, Errington (1938) did find in several cases of pellets ejected by the red-shouldered- and red-tailed hawks pellets were disgorged that contained undigested portions. This was particularly true when feedings were made shortly before a pellet was ready to be ejected.

The slow movement of the stomach walls, and consequently little mixing of the stomach contents, might possibly be offered as an explanation of the recordings of Errington (1938) and Reed (1925), working with the great horned owl, and Hibbert-Ware (1928), from data on the little owl. All came to the conclusion that pellets of different feedings, when contained in the stomach at the same time, remained separated. This was not the case in results of several experiments conducted by the author with the great horned owl. In one case, after the feeding of a large portion of a small muskrat followed twenty-four hours by two English sparrows, and another case in which the feeding of two rats was followed by one starling, the pellets ejected contained the hair and feather residues equally free of indigested material and evenly interspersed.

It was found in these experiments that hawks were capable of digesting both bird and mammal bones. The owls, in some instances, digested the bones of small birds but never mammal bones. These findings were noted by other investigators, notably, Errington (1930, 1938). A comparison of gastric excretions in hawks and owls for free and total acidity has not yet been attempted. It is quite possible that the results of a comparison of this nature would explain the differences of digestive power between hawks and owls.

Although the gastric juices of hawks has not been analyzed to determine the free and total acidity, Reed (1928) did examine gastric juices of the great horned owl. His results showed the free acidity to be nil, while total acidity was exceedingly low--varying from .15% to .43% in the different stages of digestion.

The necessity of pellet forming material, such as bones in a feeding, if a pellet is to be ejected, was observed in several cases in the great horned owl. It was found that when the skin, feathers and flesh of a bird, exclusive of bones, was fed to the great horned owl, no pellets were regurgitated. Brooks (1929) and Hibbert-Ware (1928) are of the same opinion, observing that "in the absence of soil (?) and other roughage (doubtlessly meaning bones) soft food forms no pellets to be excreted by way of the bill"*.

Brooks in refuting the results of the paper published by Bird (1929) on the food habits of the great horned owl, in which few feathers or other bird remains were found in a small percentage of the great horned owl pellets examined, cites the results of several investigations made by Hathaway and given by Forbush (1927).

Hathaway killed several snowy owls who had been preying on ducks. Upon autopsy, he found it difficult to find duck feathers in the stomach contents. Several mice taken at a preceeding meal were easily identified. From his feeding experiments of young owls and collection of residue about nests, he also comes to the conclusion that young owls, due to the great demand of the physiologic functions of growth for calcium, do not regurgitate bones in their pellets, but have the ability to digest them.

*The comments in parenthesis are my own.

Reed (1928) also found this to be the case in young great horned owls.

As a result of this discussion, the question of just what the effect of these differential powers of digestion upon food habits data might be raised. Errington (1933) believes that because of the fact that hawk pellets are hard to find and small mammals do not show up, that pellets are not a good quanitative index to the food habits of the various hawk species. Brooks (1929) is of the opinion that because of the fact that the same owls and hawks have the habit of not eating the bones of larger prey, thus discouraging the formation of pellets, pellets are not a good indication of food taken.

If the results of the experiments thus far conducted are to be accepted, it may be concluded that pellets are not an infallible indication of food habits, but investigations such as those carried on by Laugenbach (1938), in which stomach contents were examined, give a more satisfactory result.

SUMMARY

The results of these investigations show that variations in the time of retention of hair, feathers and egg shells is greater inter-specifically than intra-specifically. In three species of <u>mammalian</u> predators studied, the total time of retention was longest for the opossum, intermediate for the skunk, and shortest for the raccoon.

In studies of the opossum little variability between the retention of hair and feathers was found either on an average scat or an average time basis. Egg shells were retained slightly longer than either hair or feathers.

In the skunk, egg shells were retained over a longer period than were feathers, while in the raccoon hair was egested in a shorter time than feathers, and egg shells were retained longer than either.

A review of the literature offers certain possible explanations for the differences in retention among species. Variations in anatomical structure and in the physiological function of the digestive tract which may have an influence on the period of retention include: Total length of the digestive tract, rate and magnitude of peristalic movement, size of the caecum, size of the colon, and character of the haustra.

Variations of retention of material fed from time to time to the same species may find explanation in the following

variables; amount and quality of food taken before and after each feeding of hair, feathers and egg shells, daily and periodic activity of the animal, which in turn may be affected by numerous other factors, individual variation and any difference in digestive function over a long or short period of time.

Retention in the hawk and owls studied does not have the importance, as far as food habits studies are concerned, that retention in mammals does. Occasionally individuals do regurgitate two or several pellets from a single feeding but this is not the usual preceedure. However, certain differences in digestion among hawks and owls do influence the results of food habits studies.

The owl studies showed a greater capacity for the digestion of bird than mammal bones. In some instances the great horned owl failed to eject any pellets following the feedings of small birds. Likewise, feathers fed without bones produced no pellets.

The red-shouldered hawk disgorged no pellets following feedings of birds. Pellets containing hair showed a much lower weight ratio of bone to hair than those from the owls. These characteristics may possibly be due to the greater digestive power of the gastric secretions of hawks. Thus, it may be concluded that in mammals the presence of hair, feathers and egg shells in feces may provide a good qualitative, but no quantitative, index of foods taken. In the case of birds, however, the varied tendencies toward the production of pellets outlined above render the same conclusion impossible. In this case, the appearance of hair or feathers in the pellets may or may not provide a qualitative index of the materials ingested.

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