AGE DETERMINATION STUDIES OF THE RACCOON (PROCYON LOTOR LINNAEUS)

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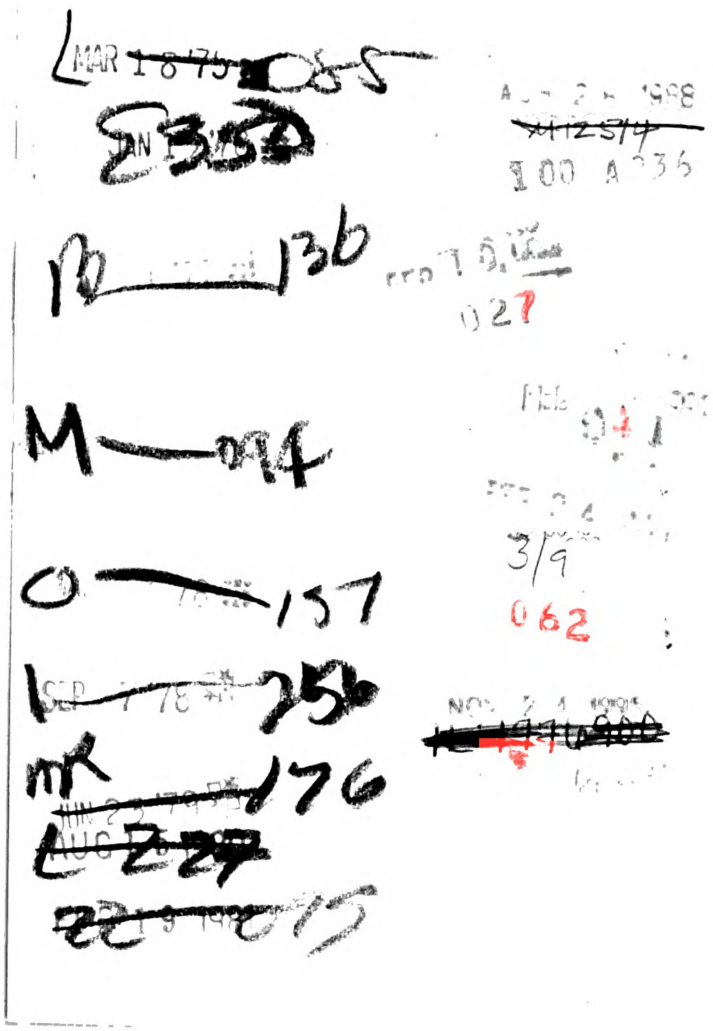

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RACCOON (*PROCYON LOTOR* LINNAEUS)

By

Robert Arnold Sundell

AN ABSTRACT

Submitted to the College of Agriculture of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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Approved Peter D. Tack

This study consisted of two phases: the investigation of (1) growth of first-year animals, and (2) age criteria of fall-caught animals.

Growth of the humerus, radius and ulna was studied in X-rays of captive specimens between two and 30 months of age. Measurements of maximum length seemed to offer a basis for estimating the ages of young animals and also for separating the 0.5 and 1.5 year classes among fall-caught specimens. The humerus, radius and ulna of a 0.5 year old animal measured 90, 89 and 109 millimeters, respectively, while comparable measurements of a 1.5 year old animal were 101, 100 and 118 millimeters.

The weights of eight juvenile wild raccoons on first capture and when later killed were used to estimate their ages based on the growth curve presented by Stuewer (1943). Three of the estimated birth dates (May 26, June 3 and 25) were later than Stuewer's latest date. As Stuewer also observed, the growth of most wild raccoons evidently is slower than that of captives.

In fall-caught specimens, skull characteristics (rostral suture closure, tooth wear and sagittal crest development), shape and texture of the baculum, length and epiphyseal fusion of the foreleg bones were combined to separate four age classes: 0.5, 1.5, 2.5 and older-than-2.5 years.

On 13 skulls of 0.5 year old animals, all the sutures of the rostrum were distinct. On the skull of one 1.5 year old animal, all the rostral sutures were distinct except the nasofrontal and nasopremaxillary sutures which were nearly fused but still discernible as indistinct lines. On five specimens 2.5 years old or older, all the rostral sutures were nearly or completely fused.

The molar cusps of 13 skulls of 0.5 year old specimens were sharp while those of one 1.5 and one 2.5 year old specimens were rounded or slightly flat-

tened. On four specimens more than 2.5 years of age, the molar cusps were much worn and nearly or completely level with the intercusp tooth surfaces.

Sagittal crest development was variable but in general the 0.5 year old male specimens exhibited temporal ridges which were fairly straight, approximately parallel and flattened against the temporal bones. In the 1.5 year old specimen, the ridges were curved, wider than the 0.5 year olds at the point of maximum width, constricted just anterior to the lambdoidal crest and raised from the temporal bones. In the specimen 2.5 years of age, the ridges were straight, raised one to two millimeters from the temporal bones and nearly joined to form the sagittal crest characteristic of all older male specimens.

The bacula of five 0.5 year old specimens possessed small proximal ends with minutely perforated surfaces and cartilaginous ligaments on the distal ends. The bacula of five specimens 1.5 years old and older exhibited enlarged proximal ends with roughened surfaces while the cartilaginous ligaments were absent.

The degree of epiphyseal fusion of the bones of the foreleg, studied on cleaned bones and in X-rays, was defined as none in 0.5, partially fused in 1.5, and fused in specimens 2.5 years old and older.

Application of the skull criteria to a sample of 109 unknown-age wild specimens gave the following results: 0.5 years, 84; 1.5-2.5 years, 17; older-than-2.5 years, 8.

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INTRODUCTION

The raccoon (Procyon lotor Linnaeus) is an important game and fur animal throughout most of its range in the United States. In the study of population dynamics of any species, the ability to identify age classes is essential. The purpose of this study was to evaluate and refine methods used in age determination in the raccoon.

Previous Investigations

Several workers have investigated age criteria in this species. Stuewer (1943) presented growth curves indicating that young-of-the-year attain full ear length by August and full hind foot length by December. He separated fall juveniles from adults by weight. Adults were identified as those weighing over 14 pounds. Unworn upper canine teeth indicated immaturity to him, while well worn teeth characterized an adult three years or older.

Petrides (1950) found that the adult baculum was characterized by a pronounced basal enlargement with roughened surfaces not present in first-year juveniles. He also found that X-rays of the forepaws of both sexes revealed fusion of the distal epiphyses of the radius and ulna with their respective diaphyses by the third year. Complete fusion of the proximal epiphyseal plate was noted in the humerus of a four-year old. Thus, in males, using bacula and forepaw epiphyses together, first-year, second-year and older animals could be identified as such. For females, teats of those which had bred were found to be enlarged, dark and wrinkled while teats of females which had not bred were

small, pinkish and smooth. Since only about 50 per cent of one and one-half year old females breed (Stuewer, 1943), however, these criteria even in combination with X-rays, did not permit the certain separation of first- and second- year females.

Sanderson (1950) found the presence of unossified cartilage on the distal end of the baculum to be characteristic of first-year juveniles. He used a body weight of 15 pounds in male adult-juvenile separation and found it to be 90 per cent accurate. Dellinger (1954) reported that the most useful aging criterion of the baculum was the condition of the basal end which was described as porous in juveniles and well ossified in adults. His conclusions regarding weight paralleled those of Sanderson (1950).

Materials Available

Materials utilized in the study included complete skeletons and skins of six captive, known-age male specimens from the Raccoon Farm of the Ohio Department of Natural Resources at Milan, Ohio. These specimens were 0.5, 1.5, 2.5, 5.5, 7.5 and 9.5 years old at the time of death. There were two additional specimens (0.5 and 1.5 years old) from Ohio with skulls lacking. Twenty-five X-rays of the leg bones and bacula of the known-age Ohio specimens were available. Thirteen skulls of known-age (12 six-months old and one 8.0 years old) wild animals and 124 skulls from unknown-age, wild specimens were secured from populations in central Michigan.

The skeletons of the eight known-age, captive specimens were cleaned by dermestids. The skulls of the 13 known-age and 15 of the unknown-age, wild animals were cleaned by maceration and dermestid action during outdoor exposure in

a wire cage. The 109 skulls from carasses of fur animals were studied in the flesh.

GROWTH OF FIRST-YEAR ANIMALS

Growth of Leg Bones

The lengths of a humerus, radius and ulna of a captive male specimen were measured from X-rays at 2, 6, 10, 12 and 30 months of age. Measurements also were made of the bones of two additional specimens 18 months old. These lengths are given in Table 1 and seem to offer a basis for estimating the ages of young animals and also for separating at least the 0.5 and 1.5 year classes among fall-caught specimens. Further investigation of variability, however, is desirable.

Weights and Birth Dates

Eight juvenile wild raccoons were handled twice each at the Rose Lake Wildlife Experiment Station near Lansing, Michigan. Their weights on first capture and when later killed by hunters were recorded by Station personnel. These weights were plotted on the growth curve for three captive juveniles presented by Stuewer (1943) and ages and birth dates were estimated. Five of the estimated dates fell within the seasonal extremes listed by Stuewer (from the first week of April to the second week of May) but three (May 26, June 3 and 25) were later than his latest date. Either the actual breeding season is longer than determined by Stuewer or the animals concerned (numbers 2, 4 and 6 of Graph 1) underwent their early development at a slower rate than Stuewer's captives and appeared younger at first capture than they actually were. Since the recapture

Table 1. Leg Bone Measurements from Known-Age Raccoons[1]

Source	Age in months	Length in millimeters		
		Humerus	Radius	Ulna
X-ray[2]	2	76	72	85
X-ray[2]	6	90[3]	89	109
X-ray[2]	10	97	96	116
X-ray[2]	12	98	97	116
Bones[4]	18	101	100	118
Bones	18	103	102	120
X-ray[2]	30	106	102	120

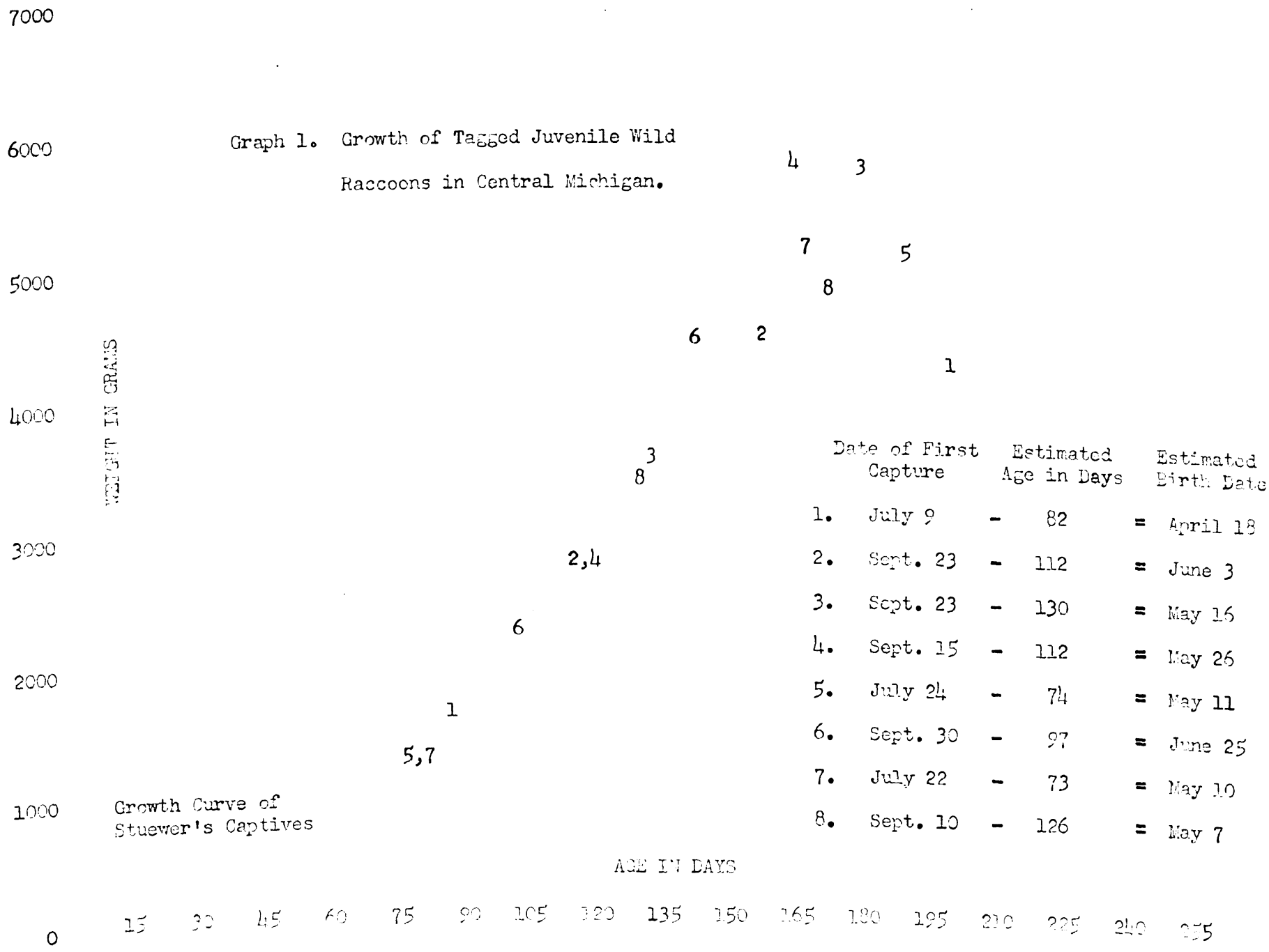
1 The bones of only one foreleg from each animal were measured.

2 Measurements from successive X-ray negatives of the same captive animal.

3 A close approximation from an X-ray in which the entire tip of the bone did not show on the plate.

4 An X-ray also was available; measurements from the X-ray and from the bones were identical.

Graph 1. Growth of Tagged Juvenile Wild Raccoons in Central Michigan.



	Date of First Capture		Estimated Age in Days		Estimated Birth Date
1.	July 9	-	82	=	April 18
2.	Sept. 23	-	112	=	June 3
3.	Sept. 23	-	130	=	May 16
4.	Sept. 15	-	112	=	May 26
5.	July 24	-	74	=	May 11
6.	Sept. 30	-	97	=	June 25
7.	July 22	-	73	=	May 10
8.	Sept. 10	-	126	=	May 7

weights of these particular individuals were quite close to those expected from Stuewer's curve, however, it seems likely that they actually were born late in the season near the dates indicated. As Stuewer also observed, the growth of most wild raccoons (Graph 1) evidently is slower than that of captives.

AGE CRITERIA OF FALL-CAUGHT ANIMALS

According to Stuewer (1943), most raccoons are born during April and May. Some possibly are born in June (see above). The age characteristics described beyond are presumed to be most useful in aging animals taken during fall hunting and trapping seasons, about six months or 0.5 years after birth.

Skull Characteristics

Skull characters investigated on 19 known-age specimens were closure of the sutures of the rostrum, wear of the teeth, and development of the temporal ridges and sagittal crest.

Suture closure: In the 13 known-age young-of-the-year (approximately 0.5 years old), all the rostral sutures were distinct (Figure 1). On the only known 1.5 year old specimen, the nasofrontal and nasopremaxillary sutures were nearly fused but still discernible as indistinct lines. On specimens 2.5, 5.5, 7.5, 8.0 and 9.5 years old, all of the rostral sutures were fused except that several millimeters of the anterior portion of the internasal suture were open in the 7.5 and 8.0 year old specimens. The nasopremaxillary suture was present as an indistinct line on the 5.5 and 7.5 year old skulls.

Of all the rostral sutures, the maxillopremaxillary was thought to be most

reliable in separating 0.5 year old from older specimens. On all 13 skulls of half-year old animals, this suture was distinct while on the cranium of the 1.5 year old specimen, it was fused but present as an indistinct line (Figure 1). On all five specimens of animals older than 1.5 years, it was completely fused and not evident. A possible indication of the age of fusion was found in a wild specimen aged by leg bone length as nearly ten months old. The maxillopremaxillary suture was fused but still evident as an indistinct line. The rostral area of the skull must be scraped or cleaned to permit use of this method.

Tooth wear: The reliability of the tooth wear differences in captive specimens is uncertain. According to E. D. Martin of the Ohio Division of Wildlife (personal letter), the raccoons studied at the Raccoon Farm in Milan, Ohio, were fed a mash diet composed of a variety of ground meals and meat scraps. Dr. Martin believed that there was less wear on the teeth of the game farm raccoons than would be true of raccoons feeding on a coarser natural diet. That this is likely true was borne out by a comparison of the 9.5 year captive skull with the 8.0 year wild one, wherein there was considerably more wear on the younger wild specimen. Some useful age differences in tooth wear seemed to prevail, however, in the younger age classes.

None of the 13 skulls of half-year old animals showed any evident wear on molar or premolar teeth. The tips of the canines were sharp. Slight wear was observed on the inner surfaces of the mandibular canines but could not be used to differentiate age classes. The characteristic most useful in identifying age classes seemed to be the degree of wear of the molar cusps. The molar cusps of the skulls of 0.5 year old specimens were sharp whereas they were flattened or rounded on the specimens of 1.5 and 2.5 year old animals. On specimens of ani-

mals older than 2.5 years, they were worn and nearly or completely level with the intercusp tooth surface (except for the anterior lingual paraconid cusp of the last mandibular molar which remained elevated). The mandibular molars of the specimen 2.5 years old exhibited less wear than those of the 1.5 year old animal. All four specimens older than 2.5 years had the canines much blunted and often apparently broken naturally. Degree of tooth wear was combined with rostral suture closure and sagittal crest development to separate skulls into three age classes: 0.5 years, 1.5-2.5 years, and older-than-2.5 years (see Table 3).

Temporal ridge and sagittal crest development: The development of the temporal ridges and sagittal crest was too varied to be useful by themselves in separating age classes. When combined with rostral suture closure and tooth wear, however, these criteria were helpful. On the 13 skulls of half-year old animals, the temporal ridges were fairly straight, approximately parallel and flattened against the temporal bones. The outer margins were seven to nine millimeters apart at the point of maximum width. On the skull of a 1.5 year male, these ridges were curved, 16 millimeters apart at the point of maximum width and constricted just anterior to the lambdoidal crest (Figure 2). The ridges were slightly raised from the temporal bones. On the skull of a 2.5 year old male, the ridges were straight, raised one to two millimeters from the temporal bones and nearly joined to form a sagittal crest. Sagittal crest development in females may not paralled that of males. The skull of the 8.0 year old female exhibited temporal ridges similar to the type observed on 0.5 year old male specimens. Unfortunately, only the one known-age female skull was available beyond the first-year class.

All skull criteria: In applying these criteria to a sample of 109 skulls of wild unknown-age specimens, the age classes and numbers determined were 0.5 years, 84; 1.5-2.5 years, 17; older-than-2.5 years, 8. Theoretical kill figures of a population of 109 based on a regular annual 20 per cent survival rate would be: 0.5 years, 87.2; 1.5 years, 17.4; 2.5 years, 3.5. The differences between the two sets of data were not significant (P = .01) according to chi-square tests. The large number of specimens identified as older than 2.5 years may reflect an increasing survival rate in older raccoons or a selectiveness in the sample (favoring the larger and hence older animals by trappers).

Characters of the Baculum

The size and shape differences of the baculum reported by Petrides (1950) were evident in the sample of six known-age bacula, although a rather striking exception was observed. This was the baculum of a 0.5 year old animal which showed moderate enlargement of the basal end. In an X-ray of the series of six known-age bacula, however, the penis bone of this 0.5 year old animal appeared to possess a hollow, or at least unossified, basal end while the bacula from older animals were solid. This X-ray and the baculum of the 0.5 year old specimen also exhibited cartilage on the distal end as reported by Sanderson (1950). It was not as evident on the cleaned specimen, however, as on five fresh bacula from animals which were classified as 0.5 years old according to all other criteria utilized in this study. These five bacula all possessed small basal ends while five bacula of 1.5, 2.5, 5.5, 7.5 and 9.5 year old animals exhibited pronounced basal enlargements. The cleaned baculum of a 0.5 year old raccoon ex-

hibited a proximal end which was covered with minute perforations. This agrees with Dellinger's (1954) description of the proximal end of the juvenile (apparently referring only to first-year animals) baculum as "porous". Five cleaned bacula from specimens 1.5, 2.5, 5.5, 7.5 and 9.5 years old possessed roughened proximal ends as described by Petrides (1950).

Epiphyseal Fusion of Leg Bones

Progressive fusion of all epiphyses of the long bones was investigated in both X-rays and cleaned bones. In two X-rays and four cleaned bones of two specimens 0.5 years old, the opposing margins of the diaphyses and distal epiphyses of the radius and ulna were distinct and unfused. They appeared as a double line. Corresponding X-rays and bones of 1.5 and 2.5 year old specimens showed the cartilaginous epiphyseal plate as an indistinct double line (partially fused) and as an indistinct single line (fused), respectively. No constant bone differences within the 2.5 year and older specimens were noted. The single indistinct line of separation apparently usually persists. Petrides (1950) also found no definite differences in the ossification of the distal epiphses of the radius and ulna between specimens three to four years old and those ten and eleven years of age.

Figures 3, 4 and 5 and Table 2 provide some details of X-ray differences in the distal epiphyses of the radius and ulna of 0.5, 1.5 and 2.5 year old specimens. In X-rays of a front and hind leg and in all 20 cleaned leg bones of five specimens, two 0.5, two 1.5 and one 2.5 years old, respectively, the opposing margins of the diaphyses and epiphyses of the proximal end of the humerus and the distal end of the femur were found to be particularly distinct (see Fig-

Table 2. Dates of Epiphyseal Fusion of Leg Bones of Known-Age Raccoons.

Specimen	Sex	Date of Birth	Date of X-ray	Age	Degree of Epiphyseal Fusion* of Long Bones
1	M	Early April, 1951	6/20/51	2 mos.	None; distinct double line
2	M	Early April, 1951	10/11/51	6 mos.	None; distinct double line
3	M	4/17/50	1/16/51	8 mos.	None; distinct double line
4	M	3/21/50	1/16/51	9 mos.	None; distinct double line
5	M	Early April, 1951	2/11/52	10 mos.	None; distinct double line
6	M	Early April, 1951	4/15/52	1 yr.	None; distinct double line
7	F	3/26/49	1/16/51	1½ yrs.	Partially fused; indistinct double line
8	M	4/7/49	1/16/51	1½ yrs.	Partially fused; indistinct double line
9	M	4/11/48	1/16/51	2½ yrs.	Fused; indistinct single line
10	M	4/1/45	1/16/51	5½ yrs.	Fused; indistinct single line
11	M	1943	1/16/51	7½ yrs.	Fused; indistinct single line
12	M	1941	1/16/51	9½ yrs.	Fused; indistinct single line

* See text, page 10.

ures 6 and 7).

Other Characters

Investigation of eight skeletons of known-age specimens failed to reveal any additional obvious differences between specimens of the different age classes. Structures examined included processes of the vertebrae, ribs, and pectoral and pelvic girdles.

Hairs from corresponding parts of pelts from specimens 0.5 to 9.5 years of age were mounted and measured with an optical micrometer under the microscope. No useful differences in hair diameter were observed.

COMBINED DATA FOR HALF-YEAR AGE CLASSES

A key to age determination in raccoons, so far as suitable criteria are available, is given Table 3.

SUMMARY

1. The lengths of several bones of the foreleg permitted the determination of age up to about 18 months.

2. The opposing surfaces of the diaphyses and epiphyses of the leg bones of five raccoons, two 0.5, two 1.5 and one 2.5 years old, appeared as distinct double lines, indistinct double lines and indistinct single lines, respectively, on bones and in X-rays.

3. In general, the sutures of the rostrum were found to be distinct in 0.5 year olds, distinct except for the nasofrontal and nasopremaxillary in 1.5

year olds, and indistinct or indiscernible in 2.5 year olds and older specimens.

4. Wear on the mandibular molars was observed as lacking (cusps sharply pointed) in 0.5 year olds, moderate (cusps flattened or rounded) in 1.5 and 2.5 year olds, and heavy (cusps nearly or completely level with intercusp area) in animals over 2.5 years old.

5. Temporal ridge development was observed as flattened and approximately parallel ridges in 0.5 year old males. In 1.5 year old males, the temporal ridges were slightly raised and parallel or curved. Sagittal crests usually were present in males 2.5 years old and older.

6. The proximal end of the baculum was usually small and with a minutely perforated surface in 0.5 year old males and enlarged and with a roughened surface in males 1.5 years old and older.

7. The distal end of the baculum was found to possess a cartilaginous ligament in 0.5 year old males which was absent in all older specimens.

Table 3. Multiple Key for Age Determination in the Raccoon.

Condition	Approximate Age
A. Humerus, radius and ulna approximately 90, 89 and 109 millimeters long (maximum length) respectively; opposing surfaces of diaphyses and epiphyses of leg bones evident as distinct double lines on bones and in X-rays; all sutures of the rostrum distinct; no evidence of wear on mandibular molars (cusps sharply pointed); temporal ridges in male flattened and approximately parallel; proximal end of baculum usually small and with perforated surface, distal end with cartilaginous ligament attached	6 mos.
AA. Not as in A ..... B	
B. Humerus, radius and ulna approximately 104, 101 and 119 millimeters long respectively; opposing surfaces of diaphyses and epiphyses of leg bones evident as indistinct double lines on bones and in X-rays; sutures of rostrum open except nasofrontal and nasopremaxillary which are evident on the skull as indistinct lines; some wear on mandibular molars (cusps flattened or rounded; never pointed except anterior lingual cusp on third molar); temporal ridges in male slightly raised from temporal bones and parallel or curved; proximal end of baculum enlarged and with roughened surface, distal end without cartilaginous ligament attached	1 yr. 6 mos.
BB. Not as in B C	
C. Humerus, radius and ulna approximately 106, 102 and 120 millimeters long respectively; opposing surfaces of diaphyses and epiphyses of leg bones evident as indistinct single lines on bones and in X-rays; all sutures of rostrum usually closed; wear on mandibular molars similar to 1.5 yrs. old; sagittal crest usually present in male; baculum similar to 1.5 yrs. old	2 yrs. 6 mos.
CC. Not as in C ..... D	
D. Characters as in C except for much wear on mandibular molars (cusps nearly or completely level with intercusp area)	older than 2 yrs. 6 mos.

FIGURES

Figure 1. Skulls of one-half year old (left) and one and one-half year old (right) captive male raccoons. Note the differences in the degree of closure of the rostral sutures and in the development of the temporal ridges.

Figure 2. Skulls of one-half year (upper left), one and one-half year (upper right) and two and one-half year (lower) old captive male raccoons. Note the marked differences in the temporal ridges of the three skulls.


INCHES
1
2
3
4
5
6
7
METRIC 1
2

Figure 3. X-rays of the forelimbs of a captive one-half year old raccoon. The opposing surfaces of the distal epiphyses and the diaphyses of the radius and ulna are evident as two distinct lines.

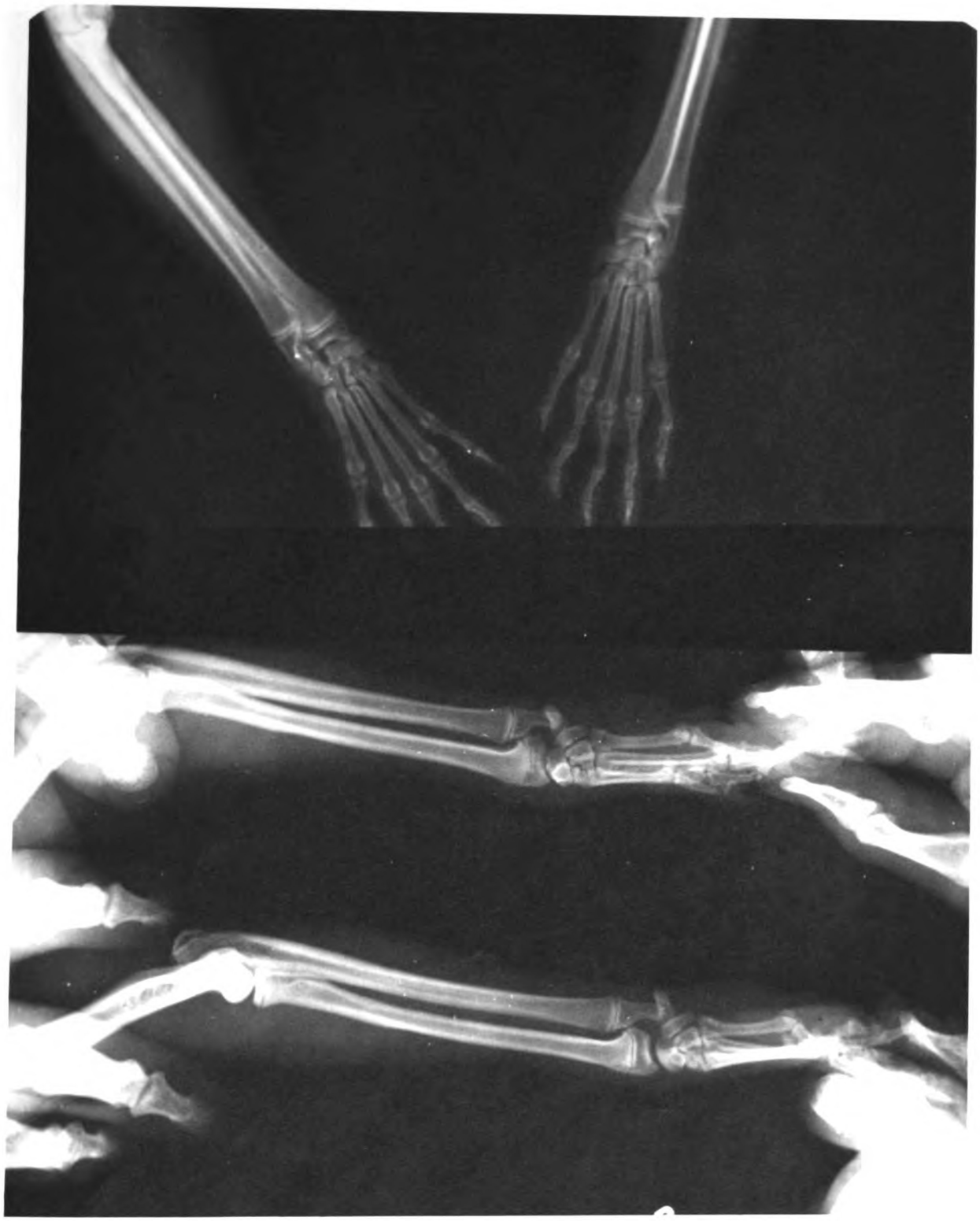


Figure 4. X-rays of the fore- and hindlimb of a captive one and one-half year old raccoon. Note the indistinct double line of separation between the distal epiphyses and the diaphyses of the radius and ulna.

Figure 5. X-rays of the fore- and hindlimb of a captive two and one-half year old raccoon. Note the indistinct single line of separation between the distal epiphyses and the diaphyses of the radius and ulna.

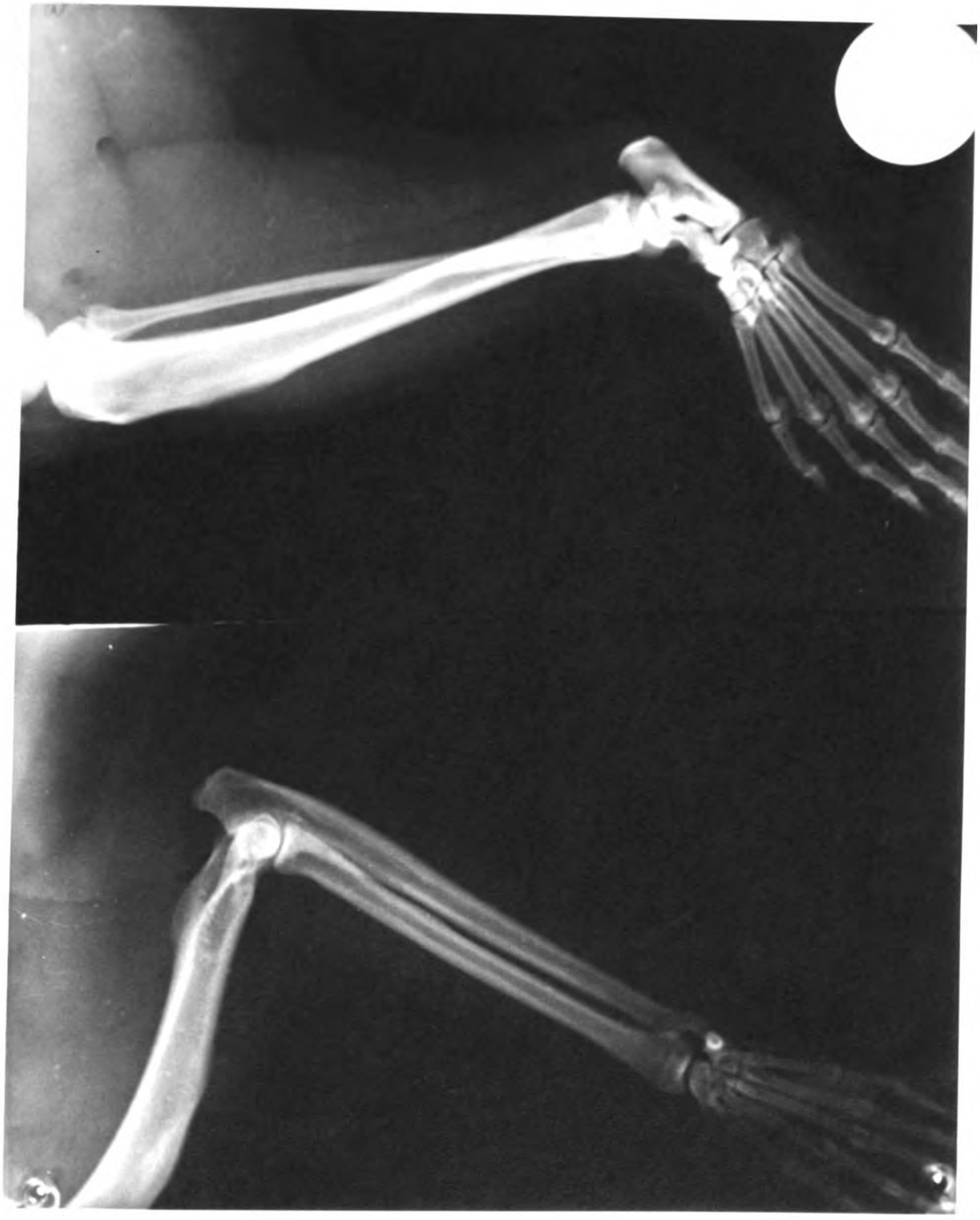


Figure 6. Proximal end of humerus of one-half (left), one and one-half (middle) and two and one-half (right) year old captive raccoons. The epiphyseal plate is evident as a distinct double line, an indistinct double line, and an indistinct single line from left to right.

Figure 7. Distal end of femur of one-half (left), one and one-half (middle) and two and one-half (right) year old captive raccoons. Note the unfused, partially fused and completely fused (left to right) epiphyseal plates.

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