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Cranial Variations and Skull Suture Obliterations as Related to Age in the Coyote (Canis latrans)

Kurt Daine
Eastern Illinois University

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Cranial variations and skull suture obliterations as related to age in the coyote (*Canis latrans*).

(TITLE)

BY

Kurt Daine

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ABSTRACT

Three criteria, skull size, development of the postorbital process, and cranial suture obliteration were examined to evaluate their effectiveness as possible age indicators in the coyote (Canis latrans). Two collections of coyote skulls were evaluated. The first was 130 skulls of known age, from Utah, which were used to compare the above characteristics to the age of the animal. The second was 151 Illinois Department of Conservation (DOC) skulls of unknown age, which were used in conjunction with the known age skulls to evaluate differences in skull size and observer and inter-observer subjectivity in the classification of suture obliterations.

Cranial measurements revealed male skulls where significantly larger ($P < 0.05$), than females. Skull sizes differed significantly between the two populations, with Illinois male skulls being larger ($P < 0.05$), than Utah males in all measurements, and Illinois females being larger ($P < 0.05$), than Utah females only in mastoid width. Known age females did not differ significantly with age, but three measurements were found significantly different ($P < 0.05$), in known age males with respect to age.

The postorbital process in the known age coyote skulls revealed some change in shape from rounded to pointed. The rounded condition was only observed in some animals under 6 years of age. Therefore, no specific age estimations could be made from this criterion.

Examination of 19 cranial sutures in the known age skulls revealed only six with age related patterns of closure. Due to the varying degree of closure found in these six sutures, the skulls could only be placed in very broad age classes, rendering the value of suture obliteration unsatisfactory in determining the age of coyotes. The subjectivity encountered in this study was found higher among different workers than between multiple observations by one worker.

Reliable aging techniques are needed by wildlife managers, who at times have to make decisions based on age structures within a population (Jean et al. 1986). For most species, a number of aging methods have been investigated in hopes of finding a technique which yields accurate results. This is also the case in coyotes, where attempts at aging have been based on cementum annuli, tooth eruption and growth, and variations in suture closure. Laws (1952), first reported cemental annulations were correlated with age, and described an aging technique based on counting annular rings laid down within the cementum of the tooth. This method has subsequently been tried on coyotes and a number of other mammals by several researchers [see Fancy (1980) for review]. Canine teeth from 30 known age coyotes were used by Linhart and Knowlton (1967), to evaluate the cementum annuli method of aging. They found the technique to be relatively accurate even in older animals. Linhart and Knowlton (1967), estimated the first opaque cementum layer is deposited at about 20-23 months of age. Allen and Kohn (1976), disagreed, reporting formation of the first cementum annuli at approximately 12 to 18 months in North Dakota coyotes. According to Linhart and Knowlton (1967), a subsequent layer of cementum is laid down each year thereafter, allowing the animals age to be estimated by counting the number of annular rings present in the cementum.

A major problem of aging by the technique used by Linhart and Knowlton (1967), was in the decalcifing, sectioning, and staining of the teeth. Jean et al. (1986), compared the accuracy of annuli counts of coyote tooth sections prepared by this histological technique, and a relatively rapid and easy grinding procedure. They found cementum annuli counts using the grinding method to agree with the standard histological preparation in 61% of the adult coyotes examined. The readability of canine teeth sectioned by the rapid grinding technique was as good as sections prepared by the time consuming histological procedures. In both methods, 95% agreement was obtained between observers with a range of plus or minus three annuli. However, in both methods observers had problems reading the annuli, with the annuli being either too diffuse or compressed.

Other researchers have encountered difficulties in distinguishing cementum layering in wolverines, (Rausch and Person, 1972, as cited by Nellis et al. 1978), grizzly bears, (Craighead et al. 1970), moose (Gasaway et al. 1978), red fox (Monson et al. 1973, as cited by Fancy 1980), and coyotes (Nellis et al. 1978). The most common problem producing error, was the presences of faint lines 1978). According to Nellis (1975 as cited by Fancy 1980), variations between observers is an unavoidable source of error when using a subjective readability index as was done by Jean et al. (1986).

Although, there have been reports of disagreement using the cementum annuli technique, several researchers have reported complete agreement between the known age specimens and age estimates from cementum annuli layer analysis (Erickson and Seliger 1969, Keiss 1969, Lockard

1972, Low and Cowan 1963, Linhart and Knowlton 1967). The accuracy obtained from the cementum annuli technique depends largely on the methods used in the preparation of the material (Fancy 1980). Longitudinal sections of the tooth root are preferred over cross sections because the cementum appears thicker making counting easier (Linhart and Knowlton 1967, Low and Cowan 1963, Gilbert 1966). Roberts (1977), concluded canine teeth of coyotes are the best for readability of cementum annuli because of the thickness of the cementum deposits.

Aging large cohorts of coyotes can be accomplished more quickly if juveniles can be readily separated from adults (Jean et al. 1986). According to Linhart and Knowlton (1967), juvenile coyotes can be separated from adult coyotes by the approximate eruption of the permanent canine tooth, and by the time of closure of the root tip canal. Permanent canines erupt between 4 to 5 months, (Linhart and Knowlton 1967), or before 7 months (Nellis et al. 1978), and the root tip canal remains open until 8 months (Linhart and Knowlton 1967). Closure of the root tip canal occurs most often during the ninth month. The most difficult groups of coyotes to age by the cementum annuli method are those less than 2 years old which were collected in the winter. This is because of the root tip closing at 9 months and the first cemental annuli not forming until 24 months (Linhart and Knowlton 1967).

The eruption and growth of the canine tooth is a continual process in coyotes (Nellis et al. 1978). Therefore, the amount of C1 drop as a possible parameter in aging coyotes was examined. Unfortunately, they could not fully test the accuracy of this technique on adult coyotes because of the small number of known age animals in their sample. The sum of C1 drop was found to be well correlated with known age and therefore appeared to provide an accurate way to separate coyotes into 0-1, 1-2, and 2+ age classes. Nellis et al. (1978), also concluded juvenile coyotes can be separated from adults by canine socket tightness using a subjective appraisal rather than a measurement.

Cranial variation and suture obliteration is another possible aging technique that has been evaluated in several carnivores including raccoons, (Junge and Hoffmeister 1980; Grau et al. 1970), red foxes, (Churcher 1960), grey foxes, (Wood 1958), black bears (Marks and Erickson 1966), and coyotes, (Rogers 1965; Linhart and Knowlton 1967). Junge and Hoffmeister (1980); Grau et al. (1970) assessed raccoon ages with considerable success using skull suture obliterations. Of the eighteen sutures they examined, patterns of suture obliterations were observed which could be used as age criteria. This aging technique can even be applied to broken or crushed skulls which have some sutures still present. The accuracy of the method would then be proportional to the number of sutures remaining for examination. The red fox has also been aged using cranial variation and suture obliterations (Churcher 1960). Closure of cranial sutures, shape of the postorbital process and anterolateral processes of the nasals, texture of the temporal areas, size of the pulp cavities of the teeth and eruption of the canine teeth were used. He was able to establish a key to age the red fox using these criteria with a margin of error of 2 years. Wood (1958), applied similar criteria to the grey fox and concluded that the presphenoid/basisphenoid and the vomerine/presphenoid sutures had promise as age indicators. In black bears it was assumed that certain skull sutures would coalesce at approximately the same time in all bears, and an attempt was made to define the age classes in which these events occurred (Marks and Erickson 1966). It was found that most cranial sutures were closed by 9 years.

The use of cranial suture obliteration as an aging technique was first applied to coyotes by Rogers (1965). He examined the dorsal aspect of the presphenoid/basisphenoid suture and found it had age related closure rates. Linhart and Knowlton (1967), also examined the presphenoid/basisphenoid suture but their examination was done ventrally rather than dorsally. Other sutures that were found to have age related closure rates in raccoons have not been examined in coyotes. It appeared reasonable, therefore, to evaluate cranial characteristics as related to age in the coyote (Canis latrans). This paper is a report of findings observed during this evaluation.

Methods

Coyote skulls from two sources were examined. The USDA/APHIS Science and Technology Predator Ecology and Behavior Project, Utah State University, provided 130 known age skulls from coyotes raised in captivity or ear tagged and released for later recapture at their facility. These skulls ranged in age from 251 to 3617 days. A second group of 151 skulls were provided by George Hubert, Furbearer Biologist with the Illinois Department of Conservation. These coyotes were shot or trapped during the hunting seasons of 1977-78. Ages of 63 skulls in this collection were based on annuli counts using the canine cementum annuli technique (Linhart and Knowlton 1967). All skulls, to my knowledge, were prepared using a pressure cooker or boiled for approximately 20 minutes with the remaining flesh being scraped off.

Skulls were examined separately, by collection, on the basis of three criteria: skull size, shape of the postorbital process, and suture obliteration. Skull measurements consisted of: total length, width of the mastiod process, width of the zygomata, and length of the mandible. An independent t-test, as described by Schefler (1979), was calculated to evaluate any differences within and between populations regarding skull size and sex. To evaluate the significance of skull size verses age, a standard regression was calculated for both sexes in the known age USDA collection. Development of the postorbital process was ranked as follows: 1) pointed in shape, 2) intermediate, and 3) rounded in shape.

The age of the USDA skulls were compared to the degree of suture obliteration of 19 cranial sutures. This was not done with skulls in the DOC skull collection because their ages were unknown. All the sutures used in this evaluation are illustrated by Junge and Hoffmeister (1980), with the exception of the presphenoid/basisphenoid and vomerine/presphenoid sutures, which are illustrated by Crouch (1969). Suture obliteration was initially recorded as reported by Junge and Hoffmeister (1980), with some modifications. The amount of suture closure for the purpose of this study was as follows: 1). Fully closed having no portions of the suture visible, 2). An intermediate stage with only one-fourth of the suture being open, 3). Intermediate with one-half of the suture being open, and one-half of the suture being closed, 4). An intermediate stage with about three-fourths of the suture being open, and 5). Open with the bones being in contact and having the suture clearly visible. Following the initial five stage system of classification, obliterations were grouped into the following classes: 1). is a closed stage, made up of the previous 1 and 2 suture classifications combined, 2). is an intermediate stage and 3). is a combination of the previous 4 and 5 suture classifications. Skulls which were damaged, yielding no measurements or suture classification, were recorded as NA, that is, not available for that particular measurement or suture. The skulls were examined as a group for each individual cranial variation before proceeding to the next character, and ages were concealed until the end of the study.

Each skull was analyzed three separate times for suture obliteration and shape of the postorbital process, while skull measurements were taken only twice. Of the cranial variations taken three times the percent agreement between trials was evaluated to indicate possible investigative errors. In addition, a sample of 30 known aged skulls having ten skulls selected at random from three different age groups (0-3.5, 3.5-6.5, and 6.5-10 years old) were analyzed by two other investigators to evaluate variations between researchers. After calculating the percent agreement, skulls revealing disagreements in all three trials, or among all three investigators were considered too variable and excluded in the age estimations.

RESULTS

The first criterion examined was skull size. Measurements were taken from 130 coyote skulls from Utah and 151 skulls from Illinois (Table 1). Each criterion was measured twice for each skull and the data from both sets of measurements were in complete agreement. Males were larger than females ($P < 0.05$) in both populations and for all measurements taken (Table 1). All measurements taken of males skulls in the Illinois collection had average skull sizes significantly larger ($P < 0.05$), than those from Utah (Table 1). Females from the Illinois collection were also significantly larger ($P < 0.05$), than Utah females, but only in mastoid width (Table 1). With respect to age and skull size, females of known age were not significantly different, while males were significantly different ($P < 0.05$), in three out of four cranial measurements (Tables 2 and 3).

The second skull criterion, shape of the postorbital process, of 130 USDA skulls were classified as follows: 1). Pointed in shape, 2). Intermediate, and 3). Rounded in shape. Classification in three trials, resulted in pointed and intermediate conditions occurring in all age classes (Figure 1). The majority of skulls having a rounded postorbital process occurred in the 0 to 2 year or less age class, with only 3% of the skulls exhibiting the rounded

Table 1. Mean sizes (mm.) of skulls from coyotes taken in Utah (USDA) and Illinois (DOC).

		TOTAL LENGTH			MASTOID WIDTH			ZYGOMATA WIDTH			MANDIBLE LENGTH		
SKULLS	SEX	N	X ± STD	RANGE	N	X ± STD	RANGE	N	X ± STD	RANGE	N	X ± STD	RANGE
USDA	M	66	192 ± 6 *	175-207	71	60 ± 2 *	55-65	61	96 ± 4 *	86-102	70	142 ± 5 *	130-151
	F	56	184 ± 6	175-199	57	58 ± 2	54-62	51	93 ± 3	88-100	56	136 ± 5	126-147
DOC	M	61	198 ± 8 *a.	175-215	60	61 ± 2 *a.	57-65	52	99 ± 4 *a.	88-109	70	146 ± 6 *a.	130-159
	F	53	186 ± 10	136-210	52	58 ± 2 b.	51-63	50	93 ± 5	72-102	71	137 ± 7	100-151

An independent t-test was used to evaluate this data.

* Males significantly different from females ($P < 0.05$).

a. Males in DOC collection are significantly larger than USDA males ($P < 0.05$).

b. Females in DOC collection are significantly larger than USDA females ($P < 0.05$).

Table 2. Comparison of skull measurements, (mm.) of the USDA known age male coyote skulls in each year class.

AGE CLASS/YRS.	SKULL LENGTH *			MASTOID WIDTH *			ZYGOMATA WIDTH *			MANDIBLE LENGTH		
	N	X ± STD	RANGE	N	X ± STD	RANGE	N	X ± STD	RANGE	N	X ± STD	RANGE
0 - 2	22	189 ± 6	175-198	25	59 ± 2	55-62	18	93 ± 4	86-98	24	141 ± 6	130-150
2.5 - 4	13	192 ± 6	182-203	15	59 ± 2	57-63	13	96 ± 4	91-102	15	142 ± 4	135-149
4.5 - 6	20	193 ± 6	183-206	20	60 ± 2	56-65	20	98 ± 3	91-102	20	141 ± 4	133-151
6.5 - 8	7	198 ± 5	192-207	7	61 ± 2	59-64	6	99 ± 2	95-102	7	144 ± 4	140-150
8.5 - 10	4	194 ± 5	189-199	4	61 ± 1	60-62	4	99 ± 2	97-100	4	144 ± 2	141-147

* Measurement does differ significantly with age ($P < 0.05$).

Table 3. Comparison of skull measurements, (mm.) of the USDA known age female coyote skulls in each year class. No female skull measurements differed significantly with age.

AGE CLASS/YRS.	SKULL LENGTH			MASTOID WIDTH			ZYGOMATA WIDTH			MANDIBLE LENGTH		
	N	X ± STD	RANGE	N	X ± STD	RANGE	N	X ± STD	RANGE	N	X ± STD	RANGE
0 - 2	26	185 ± 6	175-199	27	58 ± 2	55-62	21	93 ± 3	88-99	26	136 ± 5	126-147
2.5 - 4	10	183 ± 5	177-193	10	58 ± 2	54-61	10	93 ± 4	88-100	10	135 ± 4	129-142
4.5 - 6	14	183 ± 5	175-191	14	57 ± 2	55-60	14	93 ± 3	88-99	14	134 ± 4	126-141
6.5 - 8	6	187 ± 4	181-195	6	58 ± 1	56-59	6	95 ± 3	90-98	6	139 ± 2	136-141
8.5 - 10	1	198 ± 0	198	1	61 ± 0	61	1	99 ± 0	98	1	144 ± 0	144

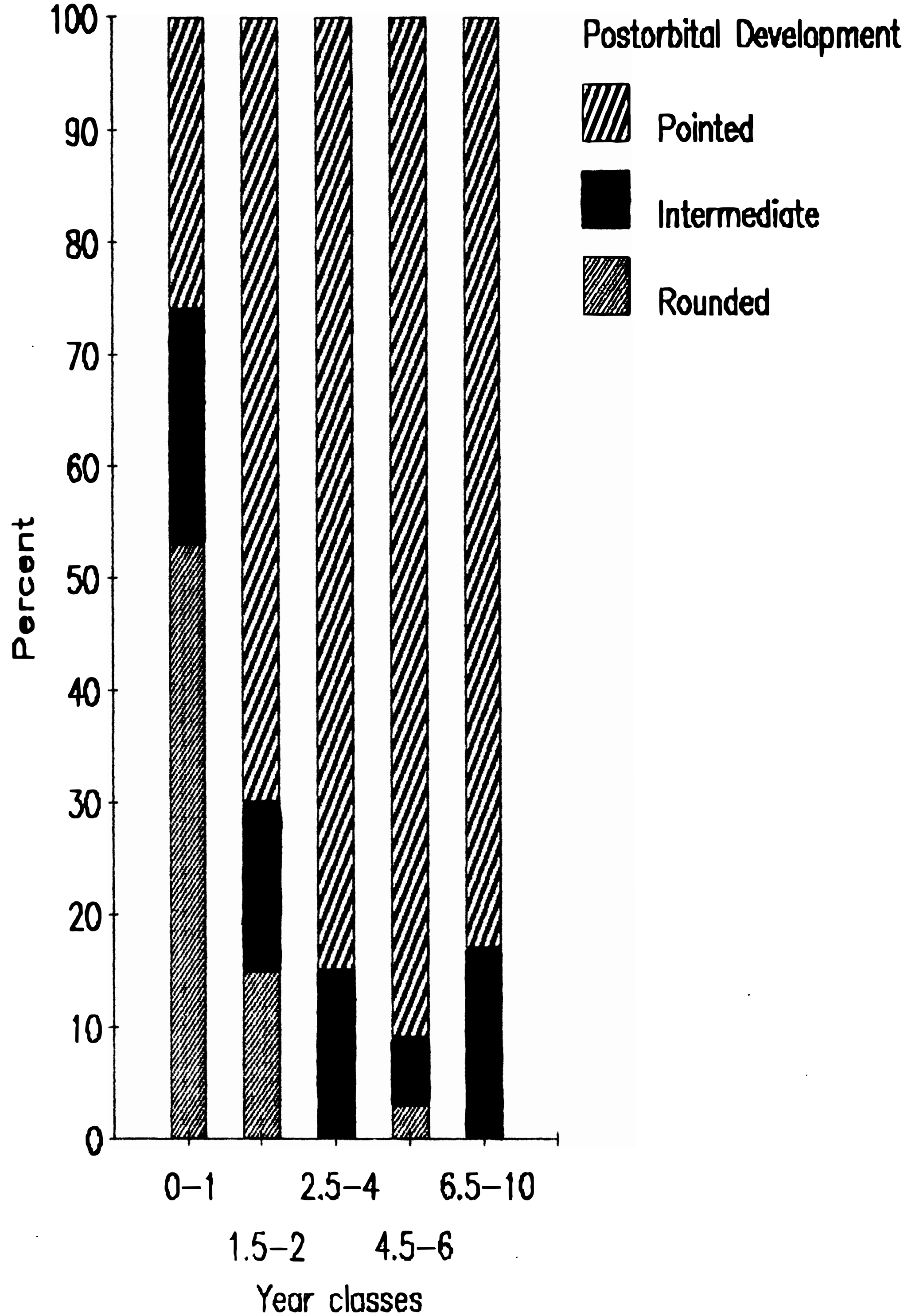

Figure 1. Postorbital process development from 130 known age coyotes from Utah.

condition in the 4.5 to 6 year class. Some subjectivity was noted in the classification of the postorbital process. Of the skulls classified by myself, 9.2% of the 130 skull readings showed variation, and when 30 randomly selected USDA skulls were examined by myself and two other workers, 47% of the readings showed variations. However, the amount of variation was not large enough, in any one skull, to warrant exclusion of a skull from the analysis.

All 130 USDA skulls were examined for suture obliteration, the third criterion. Obliteration of 19 sutures revealed only six having ageable patterns of closure (Table 4). The remaining 13 sutures were of no value having only one stage of obliteration, or all stages of obliteration represented throughout each age class (Table 4).

In three sutures, the maxillary/jugal, interpalatine, and nasofrontal, some obliteration occurred only in older animals (Table 4). Classification of the maxillary/jugal suture had 95% of the skulls open, 2% intermediate, 2% closed, and 1% not available for observation (Table 4). Skulls with the suture open were represented in every age class while skulls having closed or intermediate suture classifications were only observed in age classes 6.5 years or older (Table 4). The interpalatine suture was observed to have some closure in animals 6.5 years or older, but open and intermediate suture conditions also existed in

Table 4. Suture obliteration of 130 known age coyote skulls from Utah. Sutures were classified as 3). being completely open or nearly open, 2). being intermediate 1). being completely closed or nearly closed and NA). as not available for observation.

SUTURE	PERCENT EACH CLASS 3	2	1	NA	AGE VALUE
Exoccipital/Supraoccipital	—	—	99	1	None
Exoccipital/Basioccipital	—	—	99	1	None
Maxillary/Premaxillary	63	25	9	3	Some, see (Figure 2.)
Interparietal	88	5	6	—	None
Frontal/Parietal	99	—	1	—	None
Interfrontal	94	5	1	—	None
Maxillary/Jugal	95	2	2	1	Some closure 6.5+ years.
Basioccipital/Basisphenoid	5	2	93	—	Some open or intermediate > 2.0 years (Figure 3).
Maxillary/Palatine	98	1	1	—	None
Squamosal/Parietal	99	1	—	—	None
Interpalatine	92	6	2	—	Some closure 6.5+ years.
Squamosal/Mastiod	18	7	74	1	None
Squamosal/Jugal	92	—	—	8	None
Nasofrontal	92	3	1	4	Some closure 8.0+ years.
Nasopremaxillary	82	—	1	17	None
Pterygoid/Palatine	97	2	1	—	None
Internasal	85	1	—	14	None
Presphenoid/Basisphenoid	23	5	71	1	Some, see (figure 4.)
Vomerine/Presphenoid	91	4	2	3	None

most age classes. The nasofrontal suture exhibited some degree of suture closure in older animals, as well, having only a small percent closed in animals 8 years of age or older. In classifying the nasofrontal suture for obliteration, 92% of the skulls were open, 3% were intermediate, 4% were unavailable for classification and 1% was closed (Table 4).

The remaining three sutures also had patterns of suture closure which could be related to age, but closure was found to occur in earlier age classes. Stages of obliteration in the maxillary/premaxillary suture were widespread throughout all the represented age classes (Figure 2), but the following trends were observed. Animals with a closed maxillary/premaxillary suture indicates a possible age between 4.5 and 10 years old (Figure 2). An open suture condition indicates an animal with a possible age of 8 years or less. The maxillary/premaxillary suture also had stages of intermediate obliteration represented in age classes 2.5 years and older (Figure 2).

The basioccipital/basisphenoid suture had all three stages of suture obliteration represented in the 0 to 2 year age class (Figure 3). If the suture was closed no age estimations could be made because the closed condition was represented in every age class. However, open suture conditions occurred only in the 2 year or less age group

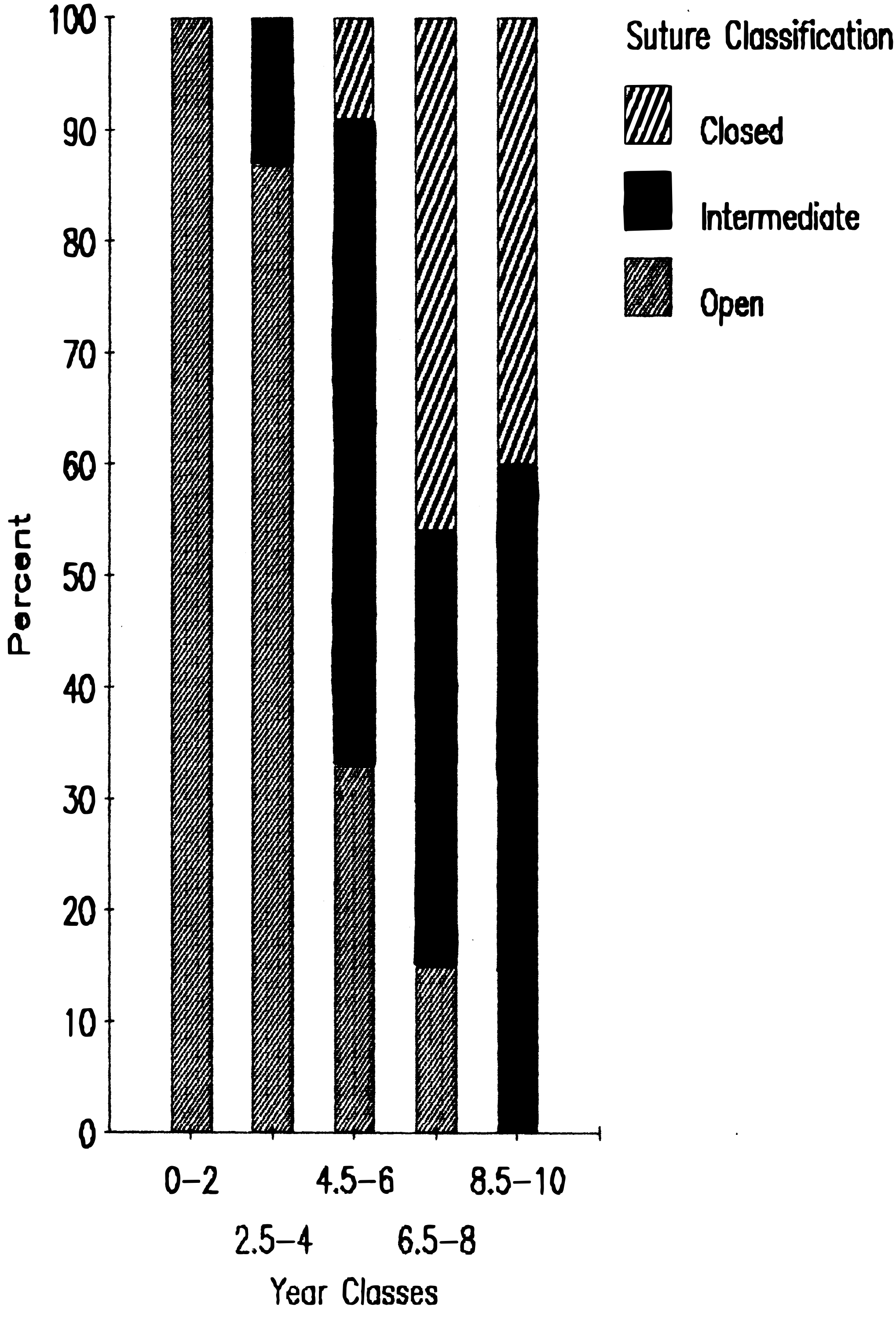

Figure 2. Maxillary/Premaxillary suture obliteration of 130 known age coyotes from Utah.

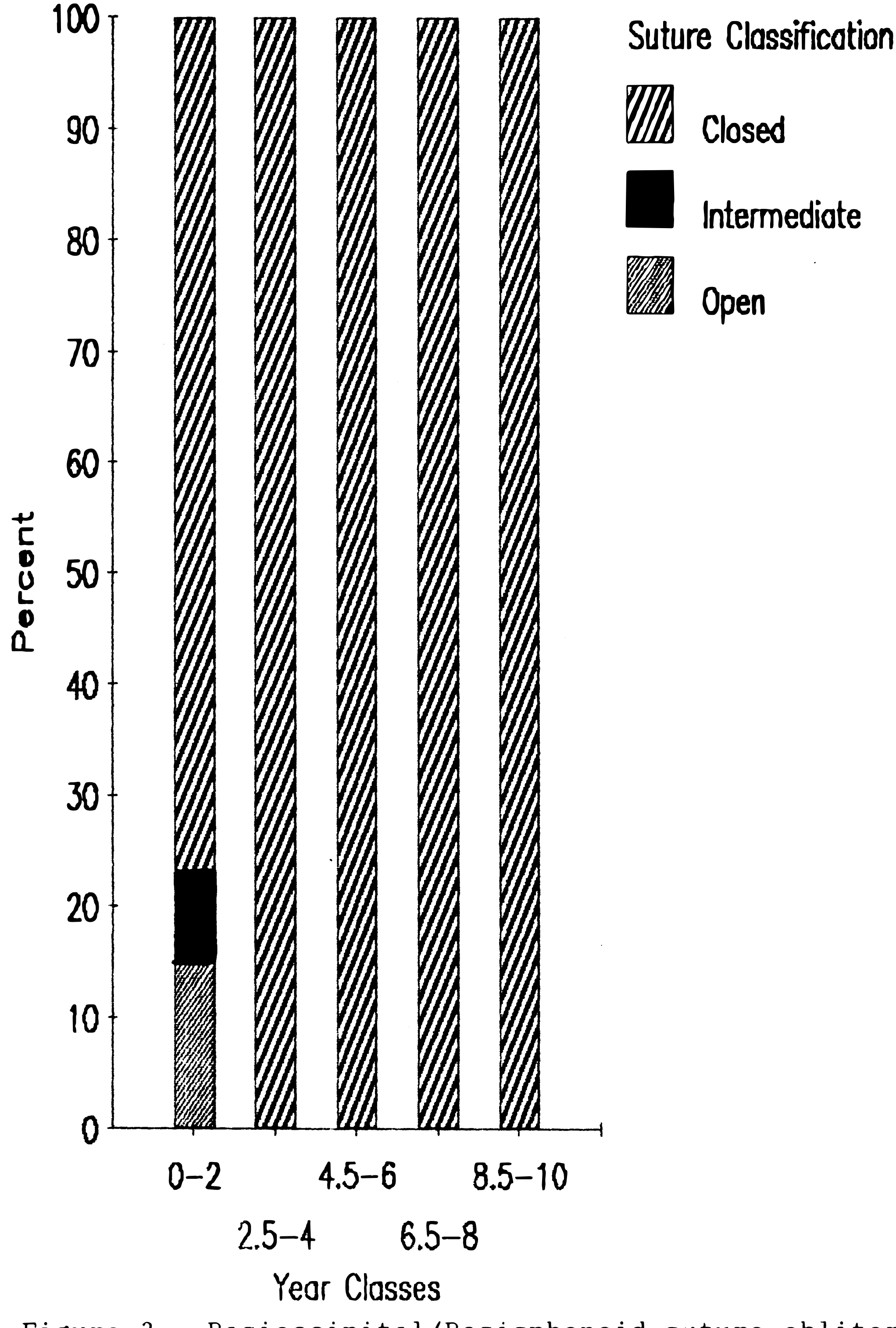

Figure 3. Basioccipital/Basisphenoid suture obliteration of 130 known age coyote skulls from Utah.

allowing animals with an open basioccipital/basisphenoid suture to be placed in this age class (Figure 3).

Suture classification of the presphenoid/basisphenoid suture resulted in 71% of the sutures being closed (Table 4). As a result of the closed sutures being present in every age group, only animals with open or intermediate suture conditions were ageable, being placed in 6 year old or less age classes (Figure 4).

Each skull from both collections were examined three times by myself, and 30 randomly selected USDA skulls were examined by myself and two other workers to evaluate the percent agreement of suture obliteration classifications between trials and between workers. Of the examinations I conducted only the maxillary/premaxillary suture, in the USDA collection, had less than 90% of the trials in complete agreement (Table 5). In the DOC collection eight sutures had less than 90% of the sutures in complete agreement between trials (Table 5).

In both collections, the maxillary/premaxillary suture had the lowest percentage of complete agreement with 88.5% in the USDA collection and 47.4% in the DOC collection (Table 5). Of all the sutures I examined, four sutures from the USDA collection and eight sutures from the DOC collection were excluded from the data due to total disagreement between trials. The percent of the sutures excluded from the USDA collection were 0.7% of the

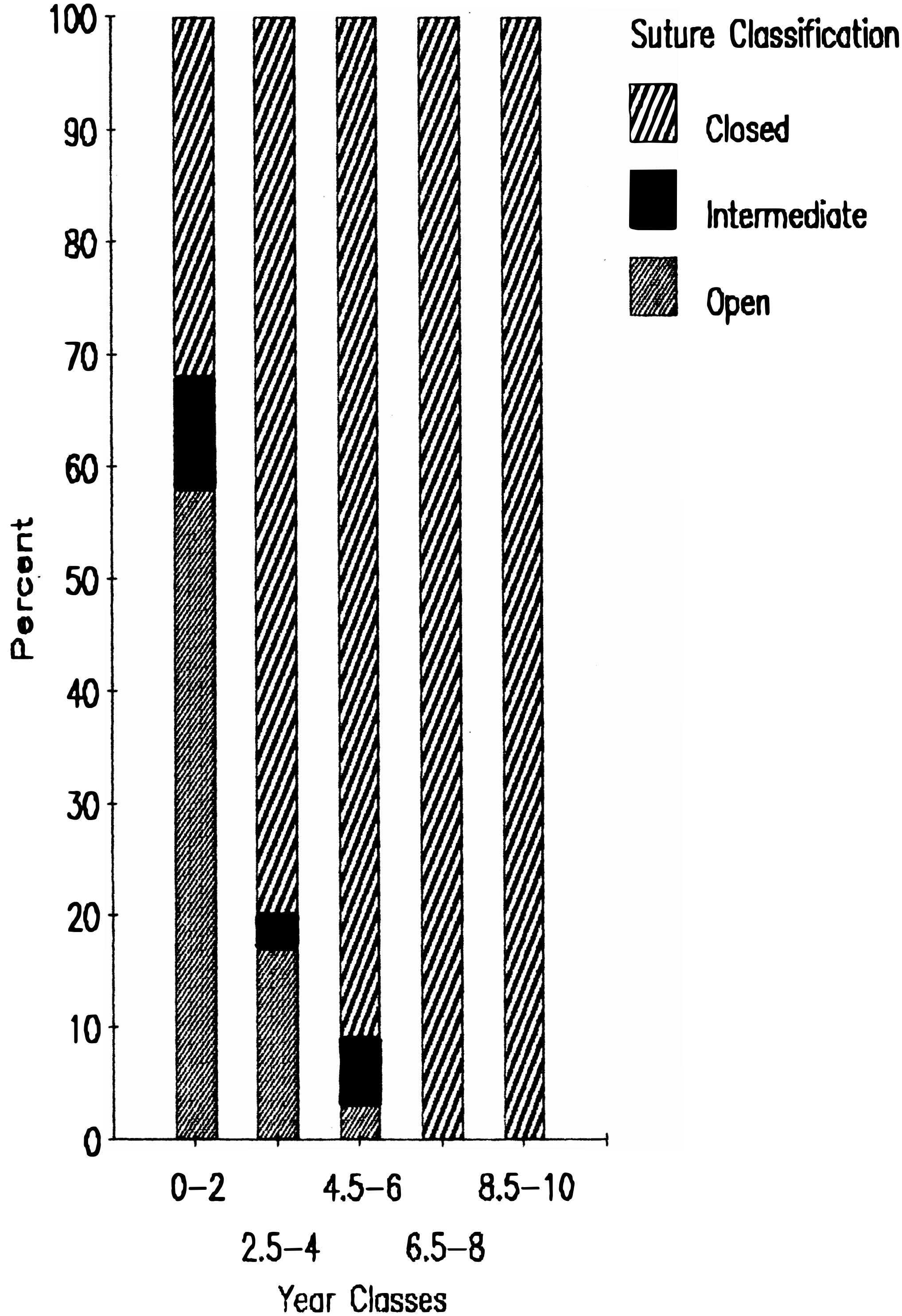

Figure 4. Presphenoid/Basisphenoid suture obliteration of 130 known age coyote skulls from Utah.

Table 5. Percent agreements regarding variation, by the principal investigator, in classifying suture obliterations of three trials in the USDA and DOC skull collections.

	THREE AGREE		TWO AGREE		ALL DISAGREE	
SUTURE	USDA /	DOC	USDA /	DOC	USDA /	DOC
Exoccipital/Supraoccipital	100.0	100.0	0.0	0.0	0.0	0.0
Exoccipital/Basioccipital	100.0	100.0	0.0	0.0	0.0	0.0
Maxillary/Premaxillary	88.5	47.4	11.5	50.0	0.0	2.6
Interparietal	96.2	84.7	3.1	15.0	0.7	0.0
Frontal/Parietal	97.0	84.0	3.0	15.4	0.0	0.6
Interparietal	94.7	90.7	5.3	9.3	0.0	0.0
Maxillary/Jugal	96.2	91.4	3.8	8.0	0.0	0.6
Basioccipital/Basisphenoid	97.0	76.0	3.0	24.0	0.0	0.0
Maxillary/Palatine	98.5	94.7	0.8	5.3	0.7	0.0
Squamosal/Parietal	94.7	82.0	5.3	18.0	0.0	0.0
Interpalatine	93.1	98.7	6.9	1.3	0.0	0.0
Squamosal/Mastoid	90.0	85.4	10.0	13.3	0.0	1.3
Squamosal/Jugal	100.0	97.4	0.0	2.6	0.0	0.0
Nasofrontal	99.3	76.0	0.7	24.0	0.0	0.0
Nasopremaxillary	100.0	99.4	0.0	0.6	0.0	0.0
Pterygoid/Palatine	96.2	97.4	3.8	2.6	0.0	0.0
Internasal	100.0	98.7	0.0	1.3	0.0	0.0
Presphenoid/Basisphenoid	91.6	95.4	7.7	4.6	0.7	0.0
Vomerine/Presphenoid	93.9	89.4	5.4	10.6	0.7	0.0
AVERAGE PERCENTS	96.2	88.9	3.7	10.8	0.1	0.3

interparietal, maxillary/palatine, presphenoid/basisphenoid, and the vomerine/presphenoid sutures (Table 5). In the DOC collection 0.6% of the frontal/parietal and maxillary/jugal and 2.6% and 1.3% of the maxillary/premaxillary and squamosal/mastoid sutures respectively were excluded (Table 5).

The amount of disagreement in suture classification was higher between workers than between multiple trials that I conducted (Tables 5 and 6). When 30 randomly selected USDA skulls were examined, 32 of the total sutures were excluded due to complete disagreement between workers. The sutures showing the largest amount of disagreement between workers is the squamosal/mastoid and the squamosal/parietal sutures (Table 6). The average percent in which three workers were in complete agreement regarding suture obliteration in the 30 randomly selected USDA skulls was 71.6% (Table 6). The average percent in which two workers agreed was 22.8 percent.

Discussion

A total of 281 coyote skulls from populations in Utah and Illinois were measured. In both collections, all the measurements revealed males to be significantly larger ($P < 0.05$) than females (Table 1). This agrees with Churcher's (1960), findings that male red foxes tend to be larger than females, in most dimensions. He also concluded

Table 6. Percent agreements between three investigators regarding variations in classifying suture obliteration of 30 randomly selected skulls from the USDA collection.

SUTURES	THREE AGREE	TWO AGREE	ALL DISAGREE
Exoccipital/Supraoccipital	100.0	0.0	0.0
Exoccipital/Basioccipital	100.0	0.0	0.0
Maxillary/Premaxillary	54.0	46.0	0.0
Interparietal	73.4	26.6	0.0
Frontal/Parietal	33.4	53.3	13.3
Interparietal	56.7	40.0	3.3
Maxillary/Jugal	60.0	30.0	10.0
Basioccipital/Basisphenoid	96.7	3.3	0.0
Maxillary/Palatine	70.0	16.7	13.7
Squamosal/Parietal	26.7	56.7	16.6
Interpalatine	76.7	20.0	3.3
Squamosal/Mastoid	33.4	43.3	23.3
Squamosal/Jugal	100.0	0.0	0.0
Nasofrontal	90.0	10.0	0.0
Nasopremaxillary	90.0	10.0	0.0
Pterygoid/Palatine	83.4	16.6	0.0
Internasal	90.0	10.0	0.0
Presphenoid/Basisphenoid	66.7	23.3	10.0
Vomerine/Presphenoid	60.0	26.7	13.3
AVERAGE PERCENTS	71. 6	22.8	5.6

that some dimensions showed a constant size difference between sexes in all year groups, while others showed not only basic size differences, but also a progressive increase in the difference with age. A size difference between male and female otters was also reported by Stephenson (1977), where the zygomatic breadth of males was significantly larger ($P < 0.05$) than females.

The cranial measurements also differed significantly ($P < 0.05$) between the two populations, with Illinois males larger in all respects than males from Utah (Table 1). In females only the mastoid width was significantly larger ($P < 0.05$), in Illinois skulls (Table 1). These size differences are contrary to what one might expect because of geographic differences and the quality of life received by the captively raised Utah coyotes as compared to the wild Illinois coyotes. Within the Utah skulls males had some significant age related difference in three of four cranial measurements (Table 2). However, the variation between measurements was so great that skull size could not be used as a valid age criterion. No comparative data have been published on coyotes, but Churcher (1960) reported similar results for the red fox, using the same measurements and Stephenson (1977) concluded the zygomatic breadth increases with age in the otter.

The postorbital process was considered as another criterion possibly changing with age. Churcher (1960) found the postorbital process in the red fox changed from triangularly pointed to spatulately rounded in adults. He concluded the change occurred after the fourth year. Conversely, I found the postorbital process changed in coyotes from round to pointed in adults. The age of animals with the rounded condition were under six years of age, with the majority being two years or less. This change in coyotes is really of no value because only broad age related correlations can be assumed.

An unavoidable source of error in evaluating the postorbital process was the subjectivity of the classifications. However, Churcher (1960) made no mention of observer or inter-observer subjectivity in his investigation of the postorbital process in red foxes. The greatest amount of subjectivity encountered, in this study, was between observers rather than between trial observations that I conducted. For example, 9.2% of 130 skulls in the USDA collection showed variation when I examined them three times and 47% of 30 randomly selected skulls from this collection showed variation upon examination by myself and two other workers. Although some subjectivity existed, the amount encountered wasn't considered high enough to exclude any skull readings from the analysis. The use of suture obliteration as a possible aging technique in the coyote was evaluated by recording the degree of suture closure of 19 sutures from 130 skulls from Utah and comparing the degree of closure to the known age of the animal. Although some researchers have reported success using suture obliteration as an aging tool in some species, I found it to be of little value in aging coyotes. By using suture obliteration in the raccoon, Junge and Hoffmeister (1980), found 11 of the 18 sutures examined had disappeared by 24 months. The disappearance of this many sutures allowed the raccoon to be aged at 2 month intervals with considerable success. Furthermore, the remaining seven sutures also showed age related patterns of closure after 24 months, but the specimens had to be placed in 6 month age intervals because of slower rates of suture closure.

In coyotes, the use of suture obliteration revealed only six sutures having some age related patterns of closure, however, in most cases only broad age relationships were evident. For example, some closure was observed in the maxillary/jugal, interpalatine and nasofrontal sutures, but this closure occurred only in some older animals rendering these sutures useless in the age determination of any animals under 6.5 years old (Table 4). Marks and Erickson (1966), reported closure of the nasofrontal suture in black bears, but only in animals 8 years old or older. Closure of the interpalatine suture was also reported in the red fox by Churcher (1960), but he made no mention of when this closure occurred.

Closure in the remaining three sutures occurred in earlier age classes, as compared to those previously mentioned, but again only general age related conclusions could be drawn. The maxillary/premaxillary suture was only useful in aging animals over 4.5 years old (Figure 2). Churcher (1960), however, had better success with the maxillary/premaxillary suture in the red fox, being able to place animals with the suture open under 4 years old and animals with the suture closed over 6 years old. In an open state, the basioccipital/basisphenoid suture, was useful in the age determination of some coyotes less than 2 years old (Figure 3). Finally, the only age related characteristics that could be drawn from the presphenoid/basisphenoid suture is open or intermediate suture conditions found in coyotes under 6 years old. This is in contrast to the findings of Rogers (1965) and Linhart and Knowlton (1967) who indicated the open condition only existed in coyotes 1 and 2 years old respectively.

In most techniques used to age mammalian species the age related changes in the criteria used are largely dependant on the individual physiology of the animal. This can involve substantial individual variation between animals (Churcher 1960). This can be compounded when using criteria which can only be recorded by subjective appraisal. This source of error was considered and evaluated in two ways. First, I examined each skull three times, and second, 30 randomly selected skulls from the USDA collection were examined by myself and two other workers. Classifications of the Maxillary/Premaxillary suture had the most disagreement in both collections between my three trials (Table 5), indicating the high amount of variability in the closure of this suture. When complete disagreement in the classification of suture obliteration was encountered, either between workers or between trials, the suture was excluded from the analysis. Of all the sutures I examined, only 12 sutures were excluded because of disagreement between all three trials. From the total sutures examined in 30 randomly selected USDA skulls, by myself and two other workers, 32 sutures were excluded from the analysis because of complete disagreement. These results indicate the degree of subjectivity in the classifications of suture obliteration is higher among different workers than among trials conducted by one worker. In other studies using cranial suture obliteration as an aging tool there were no reports of observer or inter-observer subjectivity. This is unfortunate because I feel it is an important source of error in this method of aging.

The results within this evaluation are evidence that suture obliteration is of little value as a method of age determination in the coyote. At best, only broad age estimates can be assigned to coyotes using suture obliteration, because of the variations in the time of suture closure. To date, no accurate aging methods have been reported for coyotes, and in spite of the disagreements, the most accurate method still appears to be the cementum annuli technique described by Linhart and Knowlton (1967).

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