

Age identification of the golden jackal (*Canis aureus*) and its life span in Ukraine

Keywords: age, area, body mass, golden jackal, hunting, mammals, population, skull, Ukraine

1. Introduction

An adult jackal and a coyote (*Canis latrans* Say, 1823) look alike and have roughly the same body size and weight. This resemblance is so significant that during the first findings of jackals in different European countries they were frequently misidentified as an American predator escaped from the zoo (Fig. 1).



Fig. 1 Hunters with the jackals shot in the vicinies of Zaporizhzhia, 2021.

The southern limit of the jackal range that in Eurasia encompasses the Balcan, Anatolian, Arabian Peninsulas, Indostan, Western Indochina, Iranian Plateau, southern regions of Middle Asia, valleys and lowlands of the Caucasus, is quite stable. The northern limit is intensively shifting north associated with climate warming and human-induced transformation of habitats. Within Europe, in the first half of the 20th century, the jackal only occupied the areas of Albania, Greece, Bulgaria and Croatia (SPASSOV 1989). A few encounters were also reported from Hungary, Romania and Moldova, where no local populations existed at that time. After the enforcement of the jackal hunting ban in the 1960s in the Balcan countries, its abundance and range started to grow.

During 1959-1961, the species penetrated to Romania and in 1980-1990 was reported from Austria, Italy, Macedonia and Hungary (DEMETER, SPASSOV 1993). In 1995-2000, it was encountered in Germany and Ukraine, and in 2002 – in Denmark, Poland, Belarus, Estonia and Lithuania. By now, the jackal has been registered in 27 countries, with the populations developed only in some of them (VOLOKH, ROZENKO 2016).

In Albania, the Federal Republic of Germany, Italy, Macedonia, Poland and Switzerland the species has a protection status, which in Austria and Turkey can be revised according to the situation. In Denmark, Bosnia and Herzegovina, Bulgaria, Croatia, Hungary, Kosovo, Latvia, Lithuania, Montenegro, Russian Federation, Romania, Serbia, Slovakia and Slovenia it was included in the list of game animals. In 2010, the jackal was also recognized as a game species in Ukraine (the Law about Hunting Economy and Hunting), with the hunting season lasting from 1 November to the end of February. This timing automatically prohibits the killing of pups born in the

spring-summer months. Given the dispersion of the golden jackal over the vast area and hunting for this species in Ukraine, we found it relevant to analyse the methods of its age identification enabling us to determine the life span of these animals in a new ecological environment.

2. Material and methods

The paper is based on measurements of the jackals ($n = 57$) bagged in different regions of Southern Ukraine along with the measurements ($n = 53$) and morphological examination ($n = 103$) of skulls from zoological museums (Zaporizhzhia and Odesa National Universities), and private collections. Furthermore, we used a set of different data, collected within Azov-Syvash National Nature Park, Pryazovsky National Nature Park, and in hunting lands of Zaporizhzhia, Donetsk, Mykolaiv, Odesa and Kherson regions for the period from 2001 to 2020. The majority of examined animals died on motorways due to collisions with vehicles, and much fewer were shot by hunters. To study the morphology and craniology of the jackal the standard methods, also used by our colleagues in other countries, were applied.

3. Discussion

3.1. Age identification based on the size of footprints

The footprints of an adult jackal are 5.6 cm long and 3.0 cm wide. They look similar to those of a large fox, but the paw soles are different. On the fore and hind legs, the pads of the two middle fingers in the proximal part fuse together and form a callus, shaped like a horseshoe facing forward. Therefore, it is believed that the jackal tracks in hunting areas are easily distinguished from those of young wolves or dogs. However, for me, it turned out to be a challenge since clear footprints can only be seen in exceptional cases.

Given the quick growth of pups at the beginning of the hunting season, their footprints are virtually identical to adults.

3.2. Age identification based on the animal exterior

Pups of the golden jackal are born with closed eyelids. At Tbilisi Zoo, 39 (78%) pups opened them on the 9th day, others - between the 10th and 17th days. In weak and sick animals, this process is usually delayed (DZHANASHVILI 1947). In Tajikistan, in healthy pups, the eyelids are open on the 8th–11th day, and the ears between the 10th and 13th days. In most jackals, ears begin to stand only on the 25th–30th days after birth (CHERNISHOV 1958).

Young jackals are growing fast. At the age of 2 days, pups weighed 201–214 g, at 1 month - 560–726 g, and at the age of about 4 months they were 2700–3250 g. In early September, they weighed 4200–4370 g, and in early October their weight reached 3/4 of adults (CHERNISHOV 1958). In contrast to the wolf, during the hunting season, the jackal can be only divided into two age groups according to their exterior characteristics: juveniles and adults (Table 1).

Table 1 Characteristics of exterior indices in jackals of different age

Measurements	Juveniles (5-10 months)					Adults			
	Sex	n	M±m	Min	Max	n	M±m	Min	Max
Body weight, kg	♂	9	10.0±0.33	8.5	11.5	21	12.7±0.26	10.6	16.5
	♀	7	8.9±0.21	8.0	9.2	20	11.1±0.24	9.5	13.0
Body length, cm	♂	6	73.5±0.89	71.0	76.0	16	82.9±0.91	78.0	90.0
	♀	7	75.6±2.52	70.0	85.0	15	79.3±1.44	74.0	94.1
Torso girth, cm	♂	8	47.6±0.56	45.0	50.0	15	53.3±1.17	44.9	65.0
	♀	7	47.3±2.62	40.8	62.0	14	45.9±1.10	39.0	52.0
Tail length, cm	♂	6	22.0±0.65	20.5	24.0	16	25.7±0.63	21.0	30.0
	♀	7	23.2±0.79	20.0	26.5	15	24.7±0.50	21.0	28.0

Length of hind leg, cm	♂	4	14.3±0.92	11.5	15.5	10	16.3±0.31	14.2	17.3
	♀	4	14.4±0.52	13.0	15.5	9	15.0±0.51	12.9	17.0
Length of ear, cm	♂	6	7.7±0.25	7.0	8.5	16	8.7±0.20	7.0	10.0
	♀	6	7.8±0.29	7.0	8.5	15	8.2±0.23	7.0	10.0

Females of the first year weighed 8.0–9.0 kg at the beginning of the hunting season and 8.0–9.5 kg in March next year. The weight of young males at the end of their first calendar year was equal to 8.5–10.4 kg, and in January–March of the next year it reached 10.5–11.5 kg. The height of young animals at the shoulder, with exterior parameters almost identical between sexes, amounted to 41.9±1.00 (40.0–42.0) cm, and ~46 cm at the sacrum. Adults were slightly higher, with the shoulder height of males equalling 51.8±1.60 (48.0–57.5), and that of females - 48.5±0.65 (47.0–50.0) cm. These data show that hunters should not tend to identify the golden jackal age by its exterior indicators, and other methods are required.

3.3 Age identification by fur

At birth, jackal pups are covered with soft fur, which colour varies from light grey to dark brown. At the age of one month, the juvenile hair is replaced. First, guard hairs grow on the head, back, and rump, then on the front and hind legs, and finally on the tail. Gradually, the fur colour of young animals changes turning reddish with black ripples, and in late August-early September, they almost do not differ from adults. In October–November, all juveniles have typical winter fur (CHERNISHOV 1958).

3.4 Age identification by skull sizes

Age identification by cranial indices. Since the incisors of all carnivorous mammals kept in museums or private collections are often fallen out and lost, it is usually impossible to measure the maximum length of the skull. Therefore, in the golden jackal, we use condylobasal length for this purpose. Similar to most cranial indices, it is significantly higher in adults of both sexes than in under-yearlings. The only exception is postorbital width, which decreases with age (Table 2). In very old females (~9 years old) it made up 26.8±2.50 (21.9–30.1), and in two very old males, it was equal to 35.4±3.65 (31.7–39.0) mm.

Table 2 Cranial indices (mm) of the golden jackal from Ukraine

Cranial measurements	Sex	Juveniles (5-10 months)				Adults			
		n	M±m	Min	Max	n	M±m	Min	Max
Condylobasal length	♂	9	152.8±2.53	135.6	161.1	15	159.1±1.27	153.0	167.5
	♀	14	142.4±2.10	126.9	152.0	13	153.9±1.49	140.0	161.3
Upper molar row length	♂	9	58.1±1.22	53.5	65.5	14	59.0±0.45	56.1	61.0
	♀	10	55.3±0.95	48.9	59.0	13	57.8±0.70	53.0	62.2
Zygomatic width	♂	9	82.4±2.07	74.5	91.1	14	89.9±0.96	84.0	95.2
	♀	15	79.5±1.16	20.2	26.9	13	86.4±1.21	77.2	92.0
Interorbital constriction	♂	9	24.9±0.88	21.9	28.9	14	26.7±0.48	24.0	30.1
	♀	15	23.5±0.61	20.2	26.9	13	25.8±0.73	20.0	31.1
Postorbital width	♂	9	29.5±0.63	27.0	33.0	11	28.3±0.39	26.5	31.1
	♀	15	30.4±0.79	25.7	39.3	13	29.6±1.00	26.3	40.0
Cranium height	♂	9	56.1±0.91	51.8	60.5	14	57.7±0.74	52.5	62.2
	♀	13	53.7±0.80	46.3	58.1	13	58.0±0.35	55.8	60.3

Age identification by sagittal crest length. Most jackals between the age of 5 and 9 months begin to develop sagittal and lambdoid crests. At the beginning of the hunting season, sagittal crest length on female skulls was 24.6±2.81 (16.1–34.9) mm, with the highest value (34.9 mm) recorded in a young individual bagged on February 13, 2018, two weeks before the end of the

hunting season. In adult female jackals, the sagittal crest length reaches 51.5 ± 1.34 (47.1–55.4), and in old females, which are very rare, it exceeds 60 mm. In males under the first year this index equalled to 25.0 ± 4.07 (16.6–45.2) mm, in adults - 53.8 ± 5.35 (41.6–59.9) mm, and in very old ones it made up 60.5–65.9 mm. The longest sagittal crest was in the male killed on February 28, 2021. According to the set of morphological indices, it was at least 9 years old.

3.5 Age identification by tooth development and wear

First-year animals. By the appearance and changes in teeth of the golden jackal you can get comparatively accurate ideas about their age up to 9 months. On the 11th–14th days, the lateral (i^3) and central (i^1) primary incisors in the upper jaw erupt first. The last of the primary incisors comes in on the 17th–19th days; it is a central (i_1) incisor in the lower jaw. At the same time, primary canine teeth appear. The change of primary incisors to permanent ones occurs at the age of about 4 months, and the last, third permanent tooth (M_3) in the lower jaw erupts at the age of about 5 months. In most jackals between 9 and 12 months of age, the teeth have sharp cutting edges without any signs of wear (TARANNIKOV 1973).

Second-year animals. At this age, the central parts of the upper ($I^{1,2}$) and all lower ($I_{1,2,3}$) incisors appear slightly worn, with undamaged cusps on the upper teeth (Fig. 2: A). In some individuals, the cups on the two lower incisors may be worn off ($I_{1,2}$). Damages in the distal part of the upper and lower canines as well as those in the upper carnassial (P^4) become noticeable in the absence of its pair in the lower jaw (M_1).

Third-year animals. In jackals, the enamel on the outer side of the central incisors in the upper jaw is slightly damaged, whereas their inner lateral surfaces can be worn off even below the cusps. The biting edges of all incisors, upper and lower canine teeth acquire a rounded shape. Wear also extends to the outer cusps of the first molar (M^1) and to the outer and inner cusps of the second molar (M^2) (Fig. 2: B).

At the age older than three years, the distal surface of the upper canine ($I^{1,2}$) that used to be sharp acquires a convex and later a longitudinal-oval shape. In some older individuals, it becomes almost horizontal. In the upper jaw, the first (I^1) and second (I^2) incisors are most damaged: on their biting edges, directed towards each other at an obtuse angle (Fig. 2: C), closed strips of dentin appear. With age, the anterior and, especially, the posterior tubercles of the upper fourth premolar (P^4) becomes very worn down. In old individuals, the height of the first (M^1) and second molars (M^2) is significantly reduced. Due to this, their biting edges lose the sharpness of the tubercles, getting a convex shape. Very old jackals, which are very rare, are also characterised by severe abrasion of the central upper incisors (I^1), with the cutting edges facing each other at an angle over 180° (Fig. 2: D).

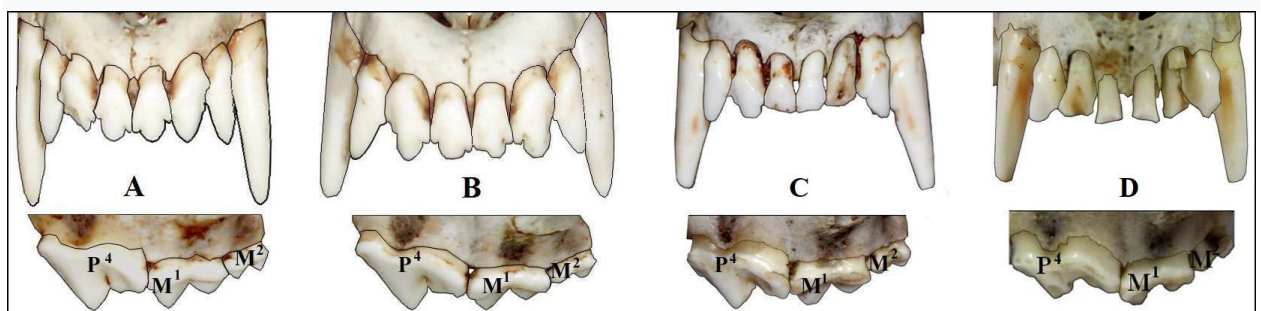


Fig. 2 Condition of teeth in the upper jaw of jackals of different ages: A – 2; B – 3; C – 4-5; D ~ 6-8 years. Photo by A. Volokh

Since the age of four, the wear of jackal incisors progresses, making it difficult to determine the age. Moreover, in some individuals, on the upper central teeth (I^1 , I^2), small light brown lines and dentin spots appear, which may not be present on the lower ones (I_1 , I_2) (Fig. 3: A). In animals

older than five years, the dentin on most upper and lower incisors looks like brown islets of comparatively large size (Fig. 3: B).



Fig. 3 Condition of incisors and canines in the lower jaw of jackals of different ages: A — 4–5; B ~ 6–8 years. Photo by A. Volokh

In old jackals, the crowns of the upper central incisors (I^1 , I^2) are worn almost to the necks of the teeth. Their biting edge becomes flat, and the height is reduced by 60-70%. As a result of significant damage to the enamel, cracks and chips appear on the frontal part of these incisors. At the same time, the tops of the lateral incisors (I^3) retain their characteristic gloss, but acquire an oval shape, with small brown spots of dentin visible in the middle. The tops of the canine teeth are blunt, and vertical stripes of dentin are visible at the points where the upper and lower teeth contact each other. As for heavily worn carnassials, spots of dentin on their biting edges are hardly visible.

Having studied a significant number of the golden jackal skulls ($n > 100$), we only a few times came across skulls with broken lower and chipped upper incisors (Fig. 2: D). We never saw a skull lacking particular teeth at all.

3.6 Age identification by the root canal obliteration of canines

At a young age, the root canal of the canine tooth is the widest, occupying most of the cross section made through the root. Further, it gradually narrows due to the accumulation of dentin along its internal walls. Usually in jackals at the age of 9–12 months, the width of the canal of the upper canine teeth exceeds 0.58 mm (TARANNIKOV 1973). In Ukraine, in under-yearlings, the ratio of the largest canal width to the maximum outer diameter of the canine was 52.7%, and the smallest one to the minimum diameter was 33.3% (Fig. 4: A). In old jackals, these indices reached 26.9 and 5.77%, respectively. With age, due to the root canal obliteration, the ratio of its minimum diameter to the maximum one also decreases (Fig. 4: B).

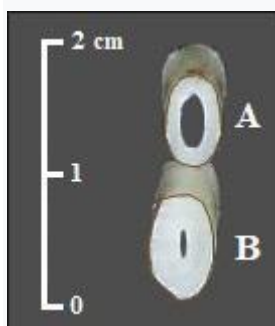


Fig. 4 Cross sections of canines of a young (A) and old (B) jackal. Photo by A. Volokh

In animals under one year of age, it was ~27%, amounting to 8–9% in old individuals. Compared to the common fox, the jackal did not show any thickening of the canine root with age. Most likely, the age of this predator by the canine root canal obliteration, with certain adjustments, can be determined using the method developed for wolves (SMIRNOV 1960).

3.7 Age identification by baculum size

Based on studies of a small number of individuals ($n = 6$) in Ukraine, we found that in male jackals at the age of about 8 months, the baculum length is equal to 4.03–4.40 cm (Fig. 5: A). In adults, it reaches 5.98 ± 0.182 (5.53–6.42) cm with a weight of 616.5 ± 85.5 (452–783) mg. In the oldest male, which age based on the condition of the incisors was about 9 years, the baculum length made up 5.99 cm, virtually equal to the average value. In contrast, the weight of its baculum was the largest (783 mg). This again indicates that this parameter is more closely related to the age of mammals than the length.



Fig. 5 Baculums of jackals of different ages: A < 1 year; B — 3–5; C ~9 years. Photo by A. Volokh

By comparison, in the black-backed jackal at the age of 3 weeks, the baculum length did not exceed 12.8 mm with the weight equalling 15 mg; at the age of about 1 year, it was 314 mg and 57.8 mm long, whereas in individuals aged two to five years these indices reached 297 mg and 56.1 mm, respectively. This bone was the longest (~66 mm) in individuals at 14 weeks, and the heaviest (~530 mg) at 38 weeks (LOMBAARD 1970). Most likely, by analogy with the African species, the males of the common jackal can be reliably divided into the main age groups by the length and weight of the baculum only before the onset of puberty.

3.8 Age identification by cranial suture obliteration

The degree of obliteration between the main occipital and main sphenoid bones can give a comparatively accurate idea of the jackal age up to 9 months. Approximately at the age of 4 months, semicircular lines of the frontal bone are developed, which, together with the extraorbital processes, first have weakly-pronounced outlines but after 6 months acquire clear contours. At the age of 7–8 months, the suture between the main occipital and main sphenoid bones starts obliterating. In young jackals, the entire outer surface of the frontal bones is dotted with small holes. This porosity along the edge of the orbits and extraorbital processes is observed only for up to 9 months (TARANNIKOV 1973). In adults, the nasal, frontal, coronal, and sagittal sutures are well defined, as well as the sutures between the maxillary and premaxillary bones, although the border between the squamous part of the temporal bone and the parietal bone is no longer visible. A

lambdoid suture between the parietal and occipital bones is also weakly-pronounced. On the palate, active processes of synarthrosis contribute to the overgrowth of the suture between the right and left maxillary and palatine bones. In very old individuals (7 years and older), the border between them is only slightly visible, although the nasal, frontal, and lambdoid sutures retain their outlines. The porosity of the bones is preserved only in adults on the orbital processes on the skull roof and is absent in old jackals.

3.9 Age identification by dentin layers

The cementum covers the entire root of jackal canine teeth, being slightly thicker on the back side of the tooth, and the thickest on the end part. The examination of over 800 histological sections belonging to 92 jackals from Uzbekistan revealed the layering in the periosteal zone of tubular bones and jaws, as well as in the dentin and cementum of the canine roots (Fig. 6).

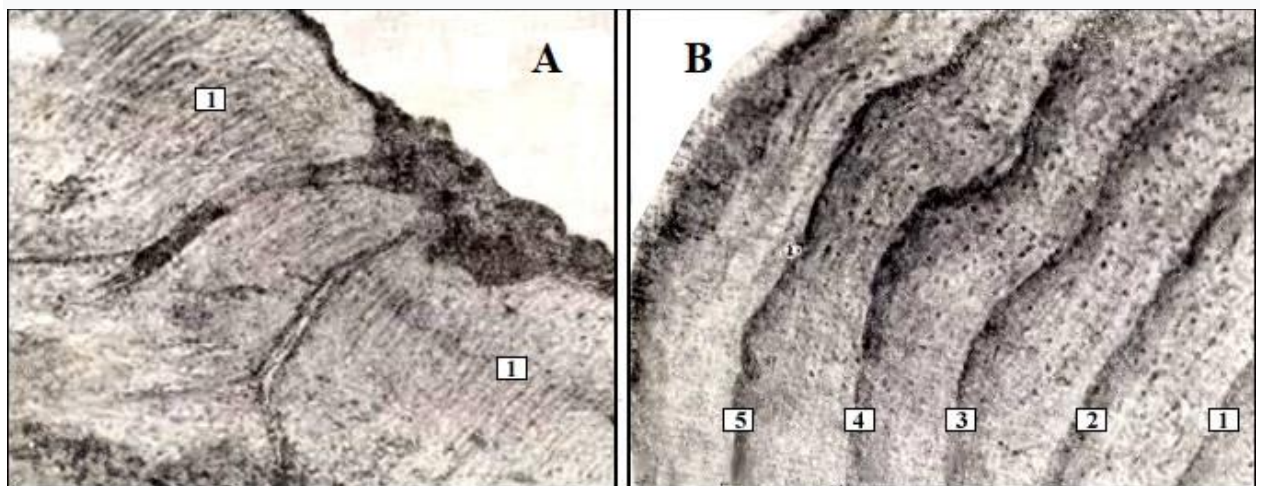


Fig. 6. Cementum layers in the upper canines of jackals of different age: A — 9 months; B — older than 5 years. Photo by V. Tarannikov (1973)

The obtained data were compared with the analysis of morphological and craniological measurements for more than 100 skulls from Tajikistan and Uzbekistan. This made it possible to reveal that the growth lines are clearly visible in the stained longitudinal sections in the cement of the upper and lower canines. The first layer is finally developed for up to one year, but in some males, this process completes before the end of the 9th month. The latter coincides with the onset of puberty. The number of layers corresponds to the number of years (TARANNIKOV 1973).

3.10 Age identification by eye lens weight

Although the data on the golden jackals are not available, in the black-backed jackal (*C. mesomelas*), which is a related species, the dry mass of eye lens had been rapidly increasing during a few first months after birth, from 18 mg in a week to 152 mg in 8 months after birth. Then, the increase noticeably slowed down, showing a significant overlap of the values among individuals aged 9 to 12 months and 1 to 5 years. A slight increase in the eye lens weight was also found in animals aged 2 to 3 years. Therefore, this method can only be applied to distinguish jackals under 7 months of age from older individuals (LOMBAARD 1971).

3.11 Life span

In the wild, most individuals of the golden jackal live as long as 5 and rarely 7 years. In zoos, some animals lived 10 (GEPTNER E. A. 1967) and even 13–15 years (TUMANOV 2009). Studies of a significant number of jackal skulls in Bulgaria (n = 228) revealed that only 6 (2.6%) individuals survived to 4, and 3 animals (1.3%) to 5+ years (RAJCHEV 2002). Despite long-term studies by Bulgarian (SPASSOV 1989; STOYANOV 2012) and Uzbek (TARANNIKOV 1973) scientists, they

failed to identify jackals with a longer lifespan. According to our research, some animals that entered the territory of Ukraine during the period of intensive expansion had a life span of 9 years.

Summary

Jackal pups of the first year are almost identical to adults by exterior, but most craniological indices of them are lower. The sagittal crest starts to develop at the age of 5 to 9 months, being 24.6 ± 2.81 (16.1–34.9) mm long in young females, and 51.5 ± 1.34 (47.1–63.4) mm in adult ones. In males up to 1 year old, its length is 25.0 ± 4.07 (16.6–45.2), and in adults the sagittal crest equals 53.8 ± 5.35 (41.6–65.9) mm.

After 5 months, all jackals have permanent teeth showing no signs of wear. In the second year of life, the tops of all incisors, canines and the upper carnassial (P^4) are slightly damaged. In the third year, the biting edges of all incisors and canines acquire a rounded shape. In animals older than 3 years, the distal surface of the upper canines becomes convex, and in older animals turns into almost horizontal. In the upper jaw, the first and second incisors are the most damaged, with the biting edges directed towards each other at an obtuse angle. In old individuals, the first upper incisors are heavily worn down, with the cutting edges facing each other at an angle of more than 180° . Since the age of four, on the upper central incisors of some jackals light brown marks and stains of dentin emerge, which may not be present on the lower ones. In animals older than 5 years, large brown islets of dentin are visible on most upper and lower incisors. In very old jackals, the crowns of the upper central incisors are worn down to the necks of the teeth, their biting edges become flat, and cracks and chips appear on the outer part.

In jackals at the age of 9–12 months, the root canal width of the upper canine usually exceeds 0.58 mm. In under-yearlings, the ratio of its largest width to the maximum external tooth diameter is 52.7%, and the smallest width to the minimum one is 33.3%. In old jackals, these values constituted 26.9 and 5.8%, respectively. With age, due to the filling of the dental canal, the ratio of its minimum diameter to the maximum also decreases. In animals up to 1 year of age, this ratio made up ~27%, and 8–9% in old individuals. In male jackals, at the age of about 8 months, the baculum length was 4.03–4.40 cm. In adults, it amounted to 5.98 ± 0.182 (5.53–6.42) cm being 616.5 ± 85.5 (452–783) mg in weight.

According to different scientists, the layered structure was revealed in the periosteal zone of tubular bones and jaws, as well as in the dentin and cement of the root part of the canines. The number of layers corresponds to the number of years. In the wild, most individuals of the golden jackal live as long as 4–5 years, and the oldest had a life span of 9 years.

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