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Age determination in European lynx *Lynx l. lynx (L.)* based on cranial development

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European lynxes *Lynx lynx lynx* were tentatively age determined using the ossification of cranial sutures and development of cranial characteristics. Cranial development seems to be more related to body size than to age, and a wide range in body size in each age-class makes it doubtful to use characters of development and cranial ossification for age determination. Age determination based on incremental lines in tooth cementum is recommended as a more reliable method.

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INTRODUCTION

Carcasses of European lynxes *Lynx l. lynx* were collected by the Directorate of Wildlife and Freshwaterfish, Game Research Division from 1960 to 1979. Carcasses were assigned to age classes based on ossification of cranial sutures and development of cranial characters using a key to age determination in European lynx developed by Birkeland (1971). The key is based on earlier investigations by Saunders (1964) on *L. l. subsolanus* from Newfoundland, and Lindemann (1955) on *L. l. lynx* from central Europe. As a control the lynxes were also age determined by counts of incremental lines in the tooth cementum. Development of cranial characters with age was investigated to establish if age determination based on cranial characteristics is reliable.

MATERIAL AND METHODS

From 1960 to 1981 it was a condition for payment of the Norwegian state bounty on lynxes that the skinned carcass was sent to the D.W.F. Game Research Division for investigation and attestation. During the years 1960—1979 the institution received 672 animals. These carcasses are the basis for this investigation.

The following characteristics were measured on each lynx skull (Fig. 1):

1. Total length of cranium. Measured between protuberantia occipitalis externa and the foremost point of sutura interincisiva.
2. Zygomatic breadth. Greatest breadth of the cranium, measured between the two arci zygomatici.
3. Ossification of synchondrosis sphenooccipitalis.
4. Degree of ossification of sutura maxilloincisiva. The ossification occurs at the alveoles of the upper canines first and continues dorsally (upwards).
5. Length of the visible part of the canine root. Measured from the cemento-enamel junction to the sutura maxilloincisiva.
6. Cranial weight. Weight of cranium plus lower mandible.
7. Distance between lineae temporalis. Measured transversally at the intersection of sutura parietofrontalis and sutura sagittalis.
8. Length of lineae temporalis measured along sutura sagittalis from the intersection with sutura parietofrontalis and to the point where the two lineae temporalis meet.
9. The lineae temporalis will converge posteriorly as the animal gets older to establish a crest, the crista sagittalis. This crest starts nearer the sutura parietofrontalis the older and bigger the animal becomes. In this investigation the crista sagittalis has been considered fully developed when the distance anteriorly to the sutura parietofrontalis is less than 10 mm. This is in accordance with Birkeland's (1971) key.

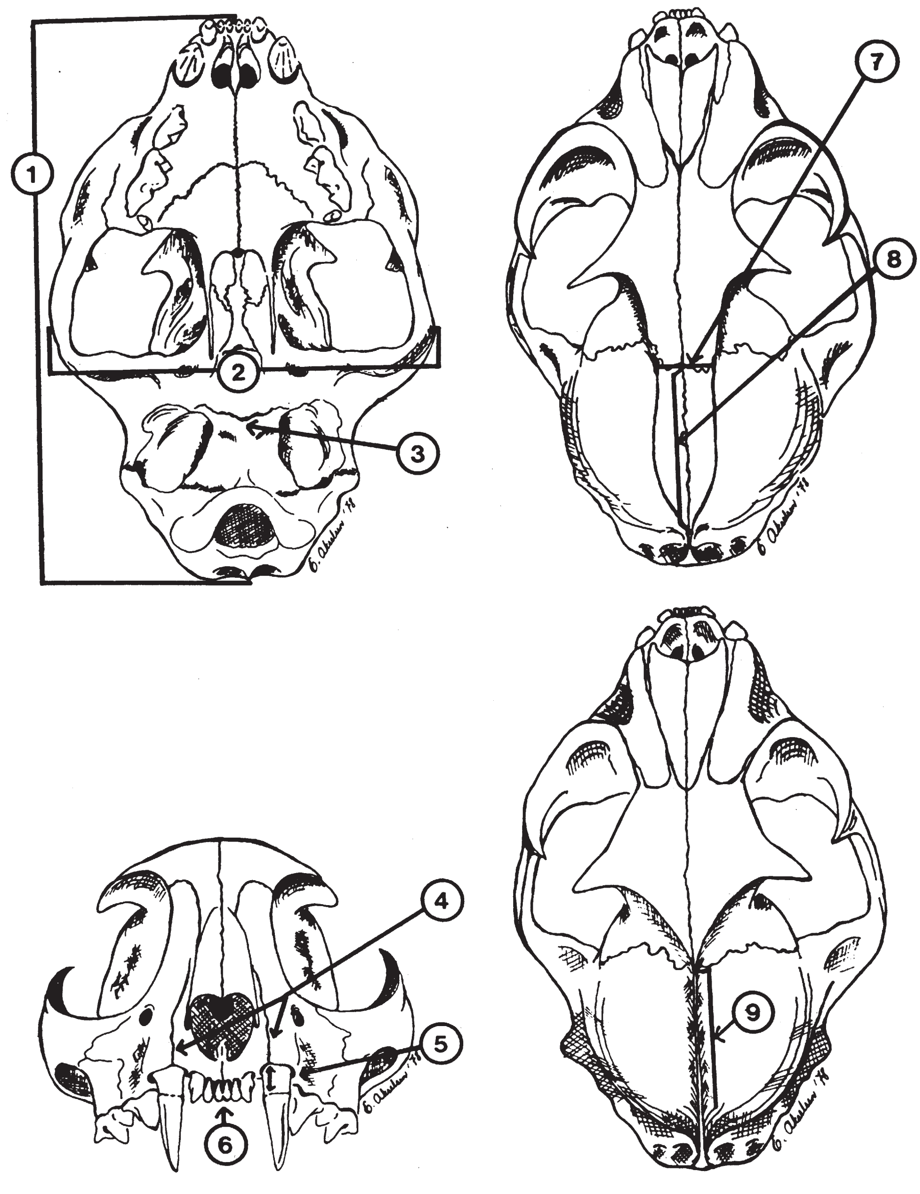

Fig. 1. Cranial measurements and characteristics used in the investigation of cranial development:

1. Total length of cranium.
2. Zygomatic breadth.
3. Synchondrosis sphenooccipitalis.
4. Sutura maxilloincisiva.
5. Visible part of the canine root.
6. Anterior edge of sutura interincisiva.
7. Distance between lineae temporalis.
8. Length of lineae temporalis.
9. Degree of development of crista sagittalis.

Table 1. Distance between lineae temporalis at sutura parietofrontalis in specimens older than 36 months of age.

	Birkeland (1971)	Observations	
		n (%)	n (%)
Males	< 4 mm	< 4 mm	> 4 mm
		67 (86%)	11(14%)
Females	< 5 mm	< 5 mm	> 5 mm
		27(36%)	49(64%)

Table 2. Length of lineae temporalis in specimens older than 36 months of age.

	Birkeland 1971	Observations		
		n (%)	n (%)	n (%)
Males	<10 mm	<10 mm	10-19 mm	>20 mm
		71(91%)	1(1%)	6(8%)
Females	>20 mm	<10 mm	10-19 mm	>20 mm
		30(39%)	3(4%)	43(57%)

Table 3. Presence of crista sagittalis.

	Age in months	Crest n(%)	No crest n(%)
	15-19	11(61%)	7(39%)
Males	20-36	78(70%)	34(30%)
	37-72	47(87%)	7(13%)
	> 72	24(100%)	0(0%)
	15-19	0(0%)	13(100%)
Females	20-36	12(19%)	51(81%)
	37-72	17(36%)	30(64%)
	> 72	13(45%)	16(55%)

Age determination

An age was assigned to each skull using Birkeland's (1971) key to age determination for European lynx. This key is based on the ossification of synchondrosis sphenooccipitalis and ossa parietalia and on the development of the crista sagittalis from the lineae temporalis.

Table 4. Ossification of synchondrosis sphenooccipitalis in relation to age. Values in percent are given for each of Birkeland's (1971) age classes (in italics). Each of his age classes is fenced in by horizontal lines for easier comparison with table 5.

Age in months	Open suture n (%)		Closed suture n (%)	
MALES				
20-36	88(96%)	*96%*	4(4%)	*4%*
37-48	6(25%)		18(75%)	
49-60	1(5%)	*16%*	20(95%)	*84%*
61-72	-	*0%*	9(100%)	*100%*
73-84	-		4(100%)	
85 ++	1(5%)	*4%*	19(95%)	*96%*
FEMALES				
20-36	46(84%)	*84%*	9(16%)	*16%*
37-48	8(47%)	*47%*	9(53%)	*53%*
49-60	3(18%)		14(82%)	
61-72	-	*10%*	13(100%)	*90%*
73-84	-	*0%*	10(100%)	*100%*
85 ++	-	*0%*	19(100%)	*100%*

Table 5. Ossification of synchondrosis sphenooccipitalis in relation to age according to Birkeland's (1971) key to determining age and sex in European lynx.

Age in months	Degree of ossification
MALES	
37-60	Open suture
61-72	The suture is closing towards the end of this period
73 ++	Closed suture
FEMALES	
37-48	Open suture
49-72	Open or closed with a highly visible trace of the suture
73-84	Closed with a visible trace of the suture
85 ++	Fully ossified. No trace of the suture

Table 6. Ossification of sutura maxilloincisiva in relation to age.

Age in months	Open suture n (%)	Ossi- fying on one side n (%)	Ossifying on both sides n (%)
MALES			
37 - 48	22(96%)	1(4%)	-
49 - 60	11(52%)	6(29%)	4(19%)
61 - 72	2(25%)	4(50%)	2(25%)
73 - 84	3(75%)	-	1(25%)
85 ++	3(15%)	3(15%)	14(70%)
FEMALES			
37 - 48	17(94%)	1(6%)	-
49 - 60	12(71%)	3(18%)	2(12%)
61 - 72	10(77%)	1(8%)	2(15%)
73 - 84	7(70%)	2(20%)	1(10%)

In addition, a canine tooth was sectioned, stained and mounted for age determination by methods described by Reimers & Nordby (1968). Ages were assigned to individuals by counting incremental lines in the tooth cementum. This method has been checked using specimens of known age, and has proved to be fairly reliable in the European lynx (Kvam 1982).

Specimens less than one year old were assigned an age by counting number of months between date of birth and known date of collection (shooting). The 15th of May was used as an estimated data of birth for all specimens (Kvam 1979).

Sex determination

Sex determination based on Birkeland's (op.cit.) key was compared with known sex recorded during the initial examination of carcasses in the laboratory.

RESULTS

A comparison was made between age assigned to a lynx based on Birkeland's (1971) key and age assigned to the same individual from counts of incremental lines in tooth cementum. Many discrepancies existed between skull characteristics he noted for certain age classes and the skull characteristics noted for the same age classes as determined by annuli in tooth cementum.

In the present material, the skulls of males older than 10 months and females older than 11

Table 7. Percent overlap between the range of male and female values for body size. (Numbers (n) of males and females in parentheses).

Age in years	Body-weight n ♂/♀	Body-length n ♂/♀	Cranial weight n ♂/♀	Total length of cranium n ♂/♀	Zygomatic-breadth n ♂/♀
0-1	95.8%(80/63)	71.9%(71/57)	79.8%(57/51)	84.7%(62/57)	76.4%(59/52)
1-2	66.7%(70/50)	54.1%(63/45)	65.9%(61/46)	53.6%(63/50)	61.9%(63/46)
2-3	51.4%(52/28)	55.2%(45/23)	33.8%(44/23)	34.7%(48/29)	47.6%(47/25)
3-4	44.1%(23/20)	59.3%(16/16)	6.9%(24/16)	20.7%(24/18)	13.5%(24/17)
4-5	91.7%(22/16)	53.3%(14/13)	15.0%(20/13)	23.7%(20/15)	3.5%(21/13)
5++	37.5%(32/39)	71.4%(27/34)	9.0%(29/36)	3.7%(31/38)	4.5%(31/38)
Average	64.5%(279/216	60.9%(236/188)	35.0%(235/185)	36.8%(248/207)	34.5%(245/191)

months had visible canine roots. As the canine grows, the alveoles restrict further growth in canine diameter, and all subsequent growth has to occur in the apex area. This will slowly push the tooth out of the skull and result in a visible canine root (see Fig. 1).

According to Birkeland's key, canines from specimens of 25 to 36 months of age do not fill the alveoles completely, thus, do not have visible tooth roots.

According to Birkeland (op. cit.) canines fill the alveoles completely in specimens older than 36 months, and specimens in this age group can be sex determined by means of length of and distance between the lineae temporalis. Tables 1 and 2 indicate that the observed values diverge from the pattern given by Birkeland (op. cit.).

The lineae temporalis will converge posteriorly as the animal gets older to establish a crest, the crista sagittalis, which according to Birkeland's key, will become fully developed only in males older than 36 months of age. The present material contains female specimens which have developed a crest as well as males older than 36 months without a crest. Consequently, the key is not in correspondence with my observations (Table 3). The youngest female lynx with a fully developed crest was 20 months old. The youngest male with a crest was 15 months old. The oldest male without a crest was 70 months old.

Birkeland's key for age determination is also based upon ossification of synchondrosis sphenooccipitalis in specimens older than 36 months of age. The tendency of the ossification to increase with age in the present material agrees with Birkeland. But the overlap between age classes is obvious. A comparison of tables 4 and 5 makes it clear that it would be difficult to group those females into age classes based on ossification of this suture. Consequently Birkeland's (op. cit.) key can neither be used to decide sex nor age for the investigated sample of European lynxes. The key seems to have been based on criteria which overlap to a degree that should not be accepted in a key to age determination.

Table 8. Development of lineae temporalis correlated with age and body-weight. Specimens younger than twelve months have not been included. Data on age and body-weight have been converted into base 10 logarithms.

	Body-weight	(n)	Age	(n)
MALES				
Distance between the l. temporalis	0.904	(135)	0.850	(139)
Length of l. temporalis	0.729	(132)	0.792	(136)
FEMALES				
Distance between the l. temporalis	0.858	(181)	0.769	(190)
Length of l. temporalis	0.551	(180)	0.588	(187)

Table 9. Age and body weight correlated to total length of cranium in females older than 12 months. n = 189. Age and body weight in base 10 logarithms.

	Length of Cranium (r)	Age (r)
Body-weight	0.900	0,439
Age	0.537	

Marks and Erickson (1966) have age determined American black bears, *Ursus americanus,* using the development of cranial characters. In addition to the criteria used in Birkeland's key, they have used the ossification of sutura maxilloincisiva. The lynx skulls showed the tendency noted by Marks and Erickson for the suture to ossify posterio-dorsally from the alveole with age. But the individual differences suggest that this criterion can only give a hint whether an animal is young or old (Table 6).

The individual differences in the development of cranial characters and body size makes discrimination of age or sex based on these parameters rather doubtful. The overlap in the range of values between males and females is obvious (Table 7).

The distance between the lineae temporalis is better correlated to body weight than to age for both males and females. This is not the case with the length of lineae temporalis, however. And neither body weight or age is very strongly correlated with this length (Table 8).

Total length of cranium in female specimens older than 12 months was compared to age and body-weight in order to study cranial development in relation to these two parameters. The results (Table 9) indicate that age and body weight do not necessarily develop proportionally to one another, and that large individual differences in body size exist within each age class. The length of the cranium is highly correlated with body weight.

DISCUSSION

Age determination using Birkeland's (1971) key of cranial developmental characters was an unreliable method for this sample of European lynx carcasses. There is reason to question the age determination of European lynx based on developmental characters. Results obtained by correlation analysis makes it clear that age and physical development need not progress in parallel. The rapid physical development in young specimens seems to leave little room for additional development in weaned animals to a degree measurable by a key to age determination. Age determination based on cranial development has been compared to age determination by incremental lines in canine root cementum in bobcat *Lynx rufus* by Conley & Jenkins (1969). They found age determination by counts of incremental lines in canine roots cementum to be a far more reliable method. This method has been tested in the European lynx using specimens of known age, and has given unambiguous results (Kvam 1982). It is reasonable to base future age determination in European lynx on counts of dark staining incremental lines in canine root cementum.

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REFERENCES

Birkeland, K. 1971. *Gaupa i Norge (The lynx in Norway).* Unpublished Cand.real. thesis, Univ. of Oslo, 107 pp. (In Norwegian).

Conley, R.M. and Jenkins, J.M. 1969. An evaluation of several techniques for determining the age of bobcats *(Lynx rufus)* in the South-east. *Proc. South-eastern Assoc. Game and Fish Commissioners Conf. 23:* 104—109.

Kvam, T. 1979. *Reproductive situation and population structure in Norwegian lynx.* Unpublished Cand.real. thesis, Univ. of Trondheim, 72 pp. (In Norwegian).

Kvam, T. 1983. Age determination in European lynx *(Lynx l. lynx)* by counts of annuli in canine tooth cementum. *Acta zool. fenn.*, in press.

Lindemann, W. 1955. Über die Jugendentwicklung beim Luchs (*Lynx l. lynx*, Kerr) und bei der Wildkatze (*Felis s. silvestris*, Schreb.). *Behaviour:* 1—44.

Marks, S.A. and Erickson, A.W. 1966. Age determination in the black bear. *J. Wildl. Manage. 30:* 389—410.

Reimers, E. & Nordby Ø. 1968. Relationship between age and tooth cementum layers in Norwegian reindeer. *J. Wildl. Manage.* 32: 957—961.

Saunders, J.K. 1964. Physical characteristics of the New Foundland lynx. *J. Mamm. 45:* 36—47.