Variation in teeth number, teeth and skull disorders in Eurasian lynx, *Lynx lynx* from Croatia

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Received 24 January 2008; Accepted 18 December 2008

A b s t r a c t . The last specimens of indigenous Eurasian lynx (*Lynx lynx*) in Croatia were exterminated around year 1903. Lynx dispersed back to Croatia after six animals were reintroduced to Slovenia from Slovakia in 1973. Considering the consequences of founder effect, genetic drift and expected high level of homozygosity, the goal of this paper was to determine variation in teeth number, teeth and skull disorders in Croatian lynx. It should also determine whether there has been a change in frequency of occurrence of developmental anomalies in relation to the population it originates from and in relation to other lynx populations. We studied 58 lynx skulls originating from the reintroduced lynx population. Changes on teeth and skull were found on 23 skulls (39.7%): supernumerary maxillary second premolar P^2 (9 skulls, 15.5%), supernumerary mandibular second molar M_2 (3 skulls, 5.2%), congenitally absent maxillary incisor (3 skulls, 6.9%), extra tooth between maxillary third incisor I^3 and canine (1 skull, 1.7%) and acquired disorders of teeth and skull (9, 15.5%).

Key words: skull, congenitally absent teeth, supernumerary teeth, reintroduced lynx

Introduction

Once spread throughout European forests Eurasian lynx was exterminated in numerous European countries during the 18th and the 19th century. It remained only in remote areas of Finland, Scandinavia, Siberia, Poland, Carpathian mountains and mountains of Western Balkan – including Kosovo, west Macedonia and Albania (B i e n i e k et al. 1998, B e g o 2001, B r e i t e n m o s e r - W ü r s t e n & B r e i t e n m o s e r 2001, H r i s t o v s k i 2001, P a n a y o t o p o u l o u 2001, P a u n o v i ć et al. 2001, S o l d o 2001, S p a s s o v et al. 2001, Z l a t a n o v a et al. 2001). The last specimens of indigenous lynx in Croatia were exterminated in the area of Gorski kotar around year 1903 (F r k o v i ć 2001). After that, during the 20th century lynx was not present in Croatia for over 70 years. However, lynx dispersed to Croatia after three females and three males were reintroduced to Slovenia from

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Slovakia in 1973 (Čop 1988). The size of recent population in Croatia is estimated up to 60 animals (Fišt et al. 2004). Lynx in Croatia is strictly protected species since 1995.

The permanent tooth formula for the whole genus *Lynx* is I3/3, C1/1, P2/2, M1/1, each maxilla and mandible has three incisors (I), one canine (C), two premolars (P) and one molar (M). Deciduous teeth formula lacks maxillary and mandibular first molar (García-Perea 1996). It is generally agreed that shape, size, and presence or absence of a tooth are under a strong genetic control (Wolsan 1984). Maxillary second premolar (P^2) and mandibular second molar (M_2) are rare in genus *Lynx* (Werdelin 1987). Their presence is considered as supernumerary to the normal dentition in genus *Lynx*. The frequency of occurrence differs depending on lynx species and population (Manville 1963, Hell 1966, Kvam 1985, Russell et al. 1995, Červený & Koubek 2000, Gužvica et al. 2000). Considering the consequences of founder effect and expected high level of homozygosity, the goal of this paper was to determine variation in teeth number, teeth and skull disorders in Croatian lynx. Sex linked differences are present on lynx skulls (Andersen & Wiig 1984, García-Perea et al. 1985, Wiig & Andersen 1986, Gomerčić 2005). This paper contributes to research on sex differences in lynx skull pathology. It should also determine whether if in Croatian lynx population there has been a change in frequency of occurrence of developmental anomalies in relation to the population it originates from and in relation to other lynx populations. This paper presents the first published data on acquired disorders on lynx skulls.

Materials and Methods

This paper researches 58 lynx skulls (*Lynx lynx*), all of them originating from the reintroduced lynx population. Out of 58 skulls, 54 skulls were in owned by hunters; and four were from skeleton collection at the Biology Department Faculty of Veterinary Medicine, University of Zagreb. Skulls have been collected in various ways. A total of 43 skulls belonged to animals shot in hunt, two animals were caught in traps, two belonged to animals killed in traffic accidents, one was found in the forest, while the origin of 10 skulls remained unknown. A total of 46 skulls originated in the period from 1980 to 2004, while the location and the time of collection of 12 skulls remained unknown. The sex of individual animals was identified by examination of internal sex-organs. The age of animals was determined by enumeration of root cementum annuli (Kvam 1984). The third maxillary incisor was used for age determination (Zapata et al. 1997), instead of the canine as Crowe (1972) and Kvam (1984) did in their research. That was to avoid significant damage of the skulls which were mostly trophies. The skulls were inspected visually and lesions were recorded based on pre-determined criteria according to Miles & Grigson (1990), Verstraete at al. (1996a,b), Abbott & Verstraete (2005). No radiographs were obtained in this study.

Results

Out of 58 examined skulls, sex was known for 51 animals, 16 were males (31.4%) and 35 females (68.6%). The age was determined for 54 skulls. An average male age was 8.6±3.4 years, and 6.6±2.8 years for females. The oldest female was nine years old, while six males were older than that. The oldest one was 15 years old. Variations in teeth number, teeth and skull disorders were found on 23 skulls. It presents 39.7% of the examined sample.

Table 1. List of examined lynx skulls which showed certain variation in teeth number, teeth and skull disorders with basic data about animals (M-males, F-females).

ID	Sex	Mass (kg)	Mandible length (mm)	Year of death	Estimated age (years)	Congenital variation in teeth number	Teeth and skull disorders
LS02	M	28.0	150.5	1989	10		Incisors and canines injured, abscessed and some incisors absent
LS09	M	21.0	156.5	1990	8	Supernumerary left and right M_2	
LS10	M	19.0	162.8	1998	8		Opening in the skull on the location of left zygomatic process of the frontal bone
LS13	M	18.0	148.3	1990	4		Right P^4 and M^1 absent while their alveoli were filled with bone tissue and closed
LS14	F	6.5	123.5	1998	<1	Supernumerary left P^2 and absent left I^1 or I^2	
LS16	M	22.0	140.2	2002	6	Supernumerary right P^2	
LS20	F	17.0	149.4	1995	4	Supernumerary left P^2	Injured mandibular canine, abscessed and missing incisors
LS21			149.9		4	Absent left I^1 or I^2	
LS22	F	14.0	140.8	1984	-	Supernumerary right P^2	
LS28		20.0	168.3	1990	7		Left P^4 and M^1 absent while their alveoli were filled with bone tissue and closed
LS32	F	23.0	152.2	1987	8		Incisors and canines injured, abscessed and some incisors absent
LS34	F	14.0	128.2	1988	<1	Supernumerary left M_2	
LS38	F	23.0	147.5	1982	5	Supernumerary left M_2	
LS40	F	18.0	141.3	1986	<1	Supernumerary left P^2	
LS43	F	18.0	134.8	1982	1	Absent right I^1 or I^2	
LS49	M	22.0	158.3	1987	13	Supernumerary right P^2	Injured mandibular canine, abscessed and missing incisors
LS50	F	10.0	128.8	2002	<1	Supernumerary left and right P^2	
LS51	F	12.0	138.7	1987	8	Supernumerary right P^2	
LS53	F	17.5	144.4	1993	7		Absent right maxillary incisors and closed alveoli
LS55	F	20.0	156.1	1983	6	Supernumerary right P^2	
LS57	M	18.0	149.7	1992	10	extra tooth between left maxillary third incisor I^3 and canine	
LS59	M	15.0	160.8	2004	13		Injured mandibular canine, abscessed and missing incisors, damaged and shortened right zygomatic process of the frontal bone

Table 2. Literature review of frequency of variations in teeth number (and total sample size) in the *Lynx* genus.

	Lynx lynx, this study	Croatia, *Lynx lynx* (Gužvica et al. 2000)	Norway, *Lynx lynx* (Kvam 1985)	Czech Republic, *Lynx lynx* (Červený & Koubek 2000)	Slovakia, *Lynx lynx* (Hell 1966)	*Lynx canadiensis* (Manville 1963)	*Lynx rufus* (Manville 1963)
	N=58	N=34	N=550	N=75	N=62	N=465	N=1983
supernumerary P^2	15.5%	20.6%	1.6%	16%	12.9%	0.4%	0.2%
supernumerary M_2	5.1%		8.7%	10,7%	9.8 %		
extra tooth between I^3 and canine	1.7%			1,3%		0.4%	0.1%
absent incisors	5.1%						

Supernumerary teeth

In 9 (15.5 %) (Table 1), out of 58 examined skulls, the second maxillary premolar (P^2) was found. In three skulls left maxillary P^2 was present and on five skulls right maxillary P^2, while one skull had both, left and right one (Fig. 1a). The second maxillary premolar P^2 was found in three males (33.3%) and six females (66.7%). Considering the determined sex ratio this feature was not sex dependent. In three skulls originating from animals of up to one year of age, maxillary P^2 was recorded. Considering that out of 58 examined skulls there was a total of six animals up to one year of age, the frequency of maxillary P^2 in animals of this age category was 50%. Out of 51 animals older than one year only six (11.8%) had maxillary P^2.

Left second mandibular molar (M_2) was found in two skulls (3.4%), while one skull had both left and right second mandibular molar M_2 (1.7%) (Table 2, Fig. 1b). The total frequency of occurrence of M_2 was 5.1% of examined skulls.

Extra haplodont tooth was determined between the left maxillar third incisor I^3 and canine (Fig. 1c) on one skull (1.7%).

Congenitally absent teeth

This abnormality was recorded in 3 (5.2%) of examined skulls. In all skulls first I^1 or second I^2 maxillary incisor is considered to be congenitally absent (Fig. 1d). Absence of empty alveolus or healing process suggests their inborn character rather then teeth loss during lifetime. The

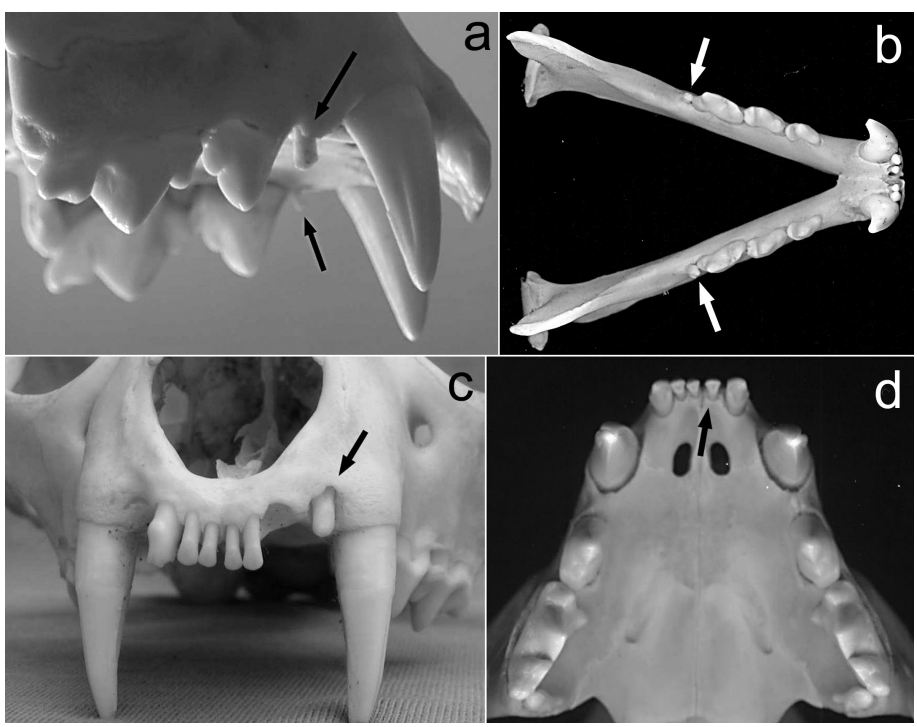

Fig. 1. Variation in teeth number in Eurasian lynx; a) supernumerary left and right maxillary second premolar P^2, skull LS50, male, 13 years; b) supernumerary left and right mandibular second molar M_2, LS09, male, 8 years; c) extra haplodont tooth between left maxillar third incisor I^3 and canine, LS57, male, 10 years; d) congenitally absent maxillary left incisors I^1 or I^2, LS14, female, <1 year.

frequency of congenital absence of maxillar incisor was 2 (3.4%) on the left and 1 (1.7%) on the right.

Disorders of teeth and skull

Disorders of teeth and skull acquired during lifetime have been observed in 9 (15.5%) skulls (Table 1). Out of those 5 animals were males, three females and sex of one animal was unknown. Considering the sex ratio of our sample (16 male and 35 female skulls) the percentage of acquired changes was 31.3% for males and 8.6% for females. In 8 (13.8%) out of 58 skulls disorders of teeth were observed, in the form of a loss or injuries affecting one or more teeth. The fourth maxillary premolar P^4 and the first maxillary molar M^1 were lost in two animals while their alveoli were filled with bone tissue and closed (Fig. 2a). Incisors and canines injured, abscessed and some of them absent (Fig. 2b, 2c and 2d), presumably from trauma, have been observed on six animals.

In two animals disorders of skull, not connected to dental patology, were observed. One skull was missing left zygomatic process of the frontal bone, with spacious opening to the frontal sinus (Fig. 3a). Edges of the opening were thickened and were not sharp, pointing that the animals had been living with that trauma for a while. Shortened angular process of the left mandible was observed on the same skull. This atrophy originates presumably from

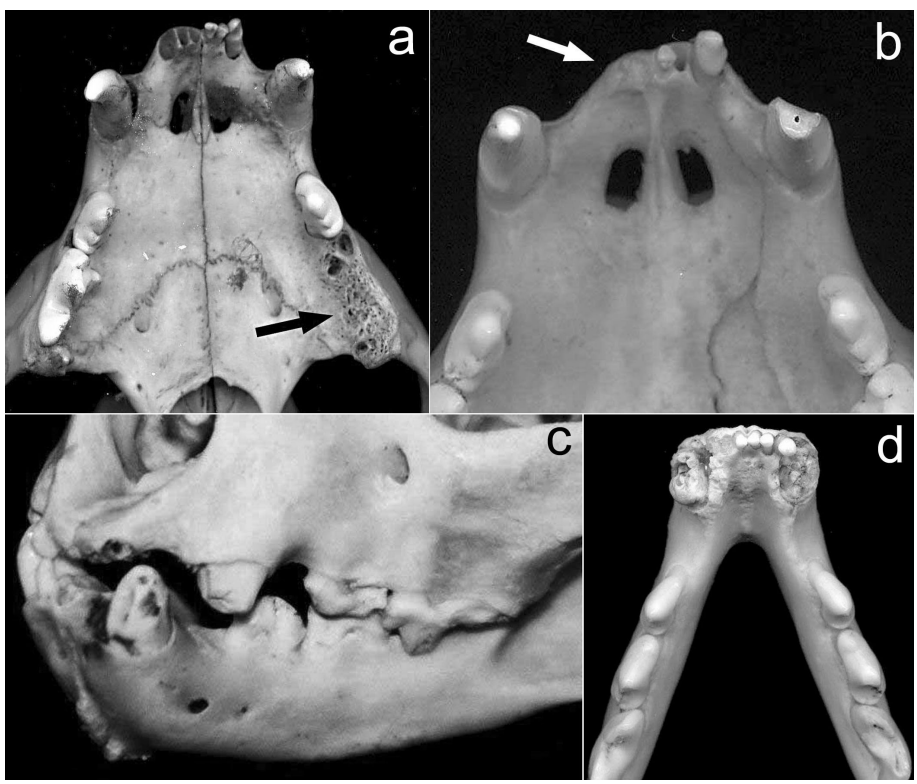

Fig. 2. Acquired teeth and skull disorders in Eurasian lynx: a) absent maxillary left first molar M^1 and fourth premolar P^4 and closed alveoli; b) absent right maxillary incisors and closed alveoli LS 53, female, 7 years; c) incisors and canines injured, abscessed and some incisors absent, LS02, male, 10 years; d) injured mandibular canine, abscessed and missing incisors, LS 59, male, 13 years.

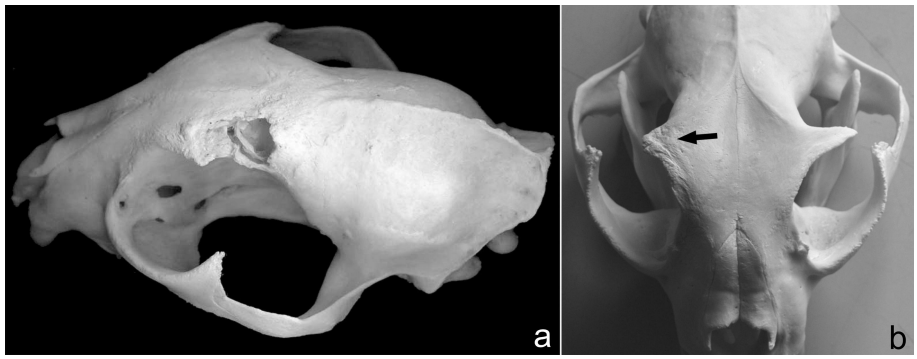

Fig. 3. Acquired skulls disorders on Eurasian lynx: a) opening in the skull (LS10, male, 8 years) on the location of left zygomatic process of the frontal bone (left); b) damaged and shortened right zygomatic process of the frontal bone (LS59, male, 13 years).

trauma. The zygomatic process of the frontal bone on another skull, damaged during the lifetime, was shorter and covered with osteophytes (Fig. 3b).

All found and described changes on skulls acquired during the lifetime exhibited healing processes, meaning that animals had been living with those changes. Changes where healing process was not been observed were not described in this paper because it could not be determined whether they were developed during the lifetime or post mortal (including being the cause of death itself).

Discussion

Supernumerary teeth in *Lynx* genus was mentioned by numerous authors (Manville 1963, Hell 1966, Kvam 1985, Červený & Koubek 2000, Gužvica et al. 2000). Table 2 shows that supernumerary P^2 and extra tooth between the maxillary third incisor I^3 and the canine are more frequent in Eurasian lynx, while it is very rare in Canadian lynx (*Lynx canadensis*) and bobcat (*Lynx rufus*).

The frequency of occurrence of P^2 differed in various Eurasian lynx populations. The frequency of Croatian population was similar to that reported for Czech and Slovak populations, whereas the Norwegian population had significantly lower frequency of occurrence. This frequency was expected for Croatian population as it was developed by reintroducing lynx from Slovakia.

The frequency of supernumerary M_2 was similar among Norwegian (8.7%), Czech (10.7%) and Slovakian (9.8%) populations, while it was lower in Croatia (5.1%). The frequency of extra tooth between maxillary third incisor I^3 and canine was very similar for Czech and Croatian lynx population. Very similar percentages of increased teeth number between Czech and Slovakian populations was understandable considering the short distance and communication between them. As Croatian population originated from Slovakia, the same frequency as in Czech and Slovakian populations was expected. This frequency matched for P^2 and extra tooth between maxillary third incisor I^3 and canine, while somewhat lower frequency of M_2 could be explained by the founders effect. This was also pointed by Gužvica et al. (2000) because of low number of reintroduced animals. Gužvica et al. (2000) have examined fewer skulls (N=34) from the same population and found occurrence of P^2 in 20.5%. Our study included bigger sample, so that might have caused the difference in

frequency. K v a m (1985) showed that in Norwegian population animals of up to one year of age had significantly higher frequency of occurrence of P^2 when compared to the animals belonging to the older age groups. G u ž v i c a et al. (2000) claimed the similar, stating that this characteristic was observed on younger animals. Results of this study were in line with their findings, as animals up to one year of age had 50% frequency of occurrence of P^2 while older animals had 10%. This study has not determined supernumerary P^2 as a sex dependent characteristic. It corresponds with the research done on other populations (K v a m 1985). Male animals had higher frequency of teeth and skull disorders acquired during the lifetime. This could be explained with the fact that male animals (8.6 years) in this study were in average older than the females (6.6 years) or that males are more aggressive and do get hurt in conflicts with other individuals more frequently.

Caries have not been determined on lynx teeth, while wolves in these areas, sharing the similar prey base, had a high occurrence (8.8%) of carries (P a v l o v i ć et al. 2007). Felids in the wild state on their strictly flesh diet are free of periodontal disease (M i l e s & G r i g s o n 1990) what is confirmed with our investigation.

It may be concluded that the teeth and skull disorders found and described here did not affect the hunting and survival abilities of examined animals, but may be an indicator of their genetic status. The found pathological changes also allowed the life of respective individuals but may have caused certain difficulties in some cases.

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