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VARIATION OF CRANIOMETRICAL CHARACTERS IN AN ARTIFICIAL POPULATION OF *CERVUS NIPPON* FROM ASKANIA-NOVA, UKRAINE

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Variation of craniometrical characters in an artificial population of *Cervus nippon* from Askania-Nova, Ukraine. — V. Smagol, V. Smagol. — Craniometrical characters of adult sika deer from an artificial population, which was created by import of animals from a natural population from the Primorsky Krai of Russia, are analysed. It was revealed that the mean value of variation (by 11 characters) of skulls of sika deer is 3.56 ± 0.35 in males and 3.89 ± 0.33 in females. Males are significantly larger than females ($p < 0.001$) by all characters. The study of craniometrical characters of the sika deer using principal component analysis showed that 93.3 % of total variance is described by the first principal component (PC1). The highest, though quite equal, factor loadings on PC1 have characters of length (full length, condylobasal length, basic length). Study results suggest that sex-related differences in *C. nippon* by craniometrical characters are expressed by general linear dimensions and by proportions of the skull. The correlation matrix of craniometrical characters of adult sika deer from the Askanian subpopulation shows a relatively weak dependence between different parameters. It was established that the coefficient of correlation in most pairs of characters varies from 0.02 to 0.96 in males and from 0.01 to 0.97 in females. The highest coefficients of correlation in both males and females ($r = 0.96$ and $r = 0.97$, respectively) are revealed between the condylobasal and basal lengths of the skull. Correlations between cranial indices are significantly lower compared to craniometrical characters. The highest coefficient of correlation in both males and females has the variation of the index of mastoid width in relation to the relative largest skull width ($r = 0.72$). Skulls of sika deer from the Askanian subpopulation (of both males and females) have significantly larger dimensions compared to those in animals from the natural population from the Primorsky Krai.

Key words: sika deer, subpopulation, craniometrical characters, artificial isolation, Askania-Nova Reserve.

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Introduction

The sika deer (*Cervus nippon hortulorum* Temm.) is a valuable decorative and game species (Bromley 1981; Igratova *et al.* 2005), which is bred in game husbandries, suburban parks, and specialised farms (Lowe *et al*. 1975; Ratcliffe 1987; Aramilev 2009; Bartoš 2009). Its high productivity, ecological plasticity, and original look contributed to the fact that this member of the family of cervids (Cervidae) became one of the most widespread introduced species in the world (Pérez-Espona *et al*. 2009; Carden *et al*. 2011).

New climatic conditions, food, and keeping conditions affect the morphology and function of various organs, behaviour, and, eventually, the existence of the species under such new conditions (Gulay 2006; Domnich *et al.* 2014; Oliger 2016). Acclimatisation of the sika deer in temperate latitudes, its cultivation in game husbandries, high aesthetic and economic significance of this species are well studied and widely discussed in the literature (Prysiazhniuk 1981*a-b*; Korchagin 2011). Nevertheless, this species is rare in the fauna of Ukraine and features of its biology, particularly in conditions of open habitats, practically have not been studied here.

Most of the studies on the sika deer's biology were conducted in forest habitats, which are common for this species, with the respective trophic base (Mirolyubov *et al*. 1948; Prysiazhniuk 1981*a-b*; Sokolov 1992; Cook *et al*. 1999; Swanson *et al*. 2009). Living conditions of the sika deer in the Askania-Nova Reserve significantly differ by both keeping approaches and climatic and trophic characteristics of the region. The sika deer have been kept in Askania-Nova since 1956 in isolated conditions. The experience of many decades showed that untraditional conditions, such as open habitat, low humidity, absence of deciduous woody fodder, are not extreme for this species and it has acclimatised quite successfully to conditions of the dry fescue-feather grass steppe.

The aim of the present work is to study the variation of craniometrical characters of the sika deer from the Askanian semi-free subpopulation that have been kept in living conditions uncommon for the species.

Material and Methods

Measurements of 43 skulls of adult sika deer from the Askanian subpopulation were taken. The skulls were passed to "The Nature of Taurica" museum of the Askania-Nova Biosphere Reserve in 2010–2017.

Skull measurement were taken following the standartised scheme (Zagorodniuk 2002). The age of animals was determined according to Mirolyubov *et al.* 1948. All measurement were taken by calliper with an accuracy of 0.1 mm. The following characters were analysed (Fig. 1): *MCL*, maximum skull length; *CBL*, condylobasal length; *BCL*, basic skull length, *ROL*, rostral length; *NAL*, nasal bones length; *DBM*, upper tooth row length; *PLL*, palatine length; *MCB*, maximum skull width; *ZYG*, zygomatic width; *IOR*, interorbital constriction width; and *CRB*, braincase width.

To a more comprehensive characterisation of craniometrical parameters of the sika deer, four indices (interrelations) were calculated:

- index of the relative length of the upper tooth row (*RDBM*) = *DBM* / *BCL* * 100;
- index of the relative maximum skull width (*RMCB*) = *MCB* / *BCL* * 100;
- index of the relative interorbital constriction width (*RIOR*) = *IOR* / *ZYG* * 100;
- index of the relative mastoid width (RZYG) = *ZYG / BCL* * 100.

The variation of the 11 craniometrical characters was studied by methods of descriptive and multivariate statistics using Statistica v.10 and PAST v.3. Missing data were replaced by regression imputation.

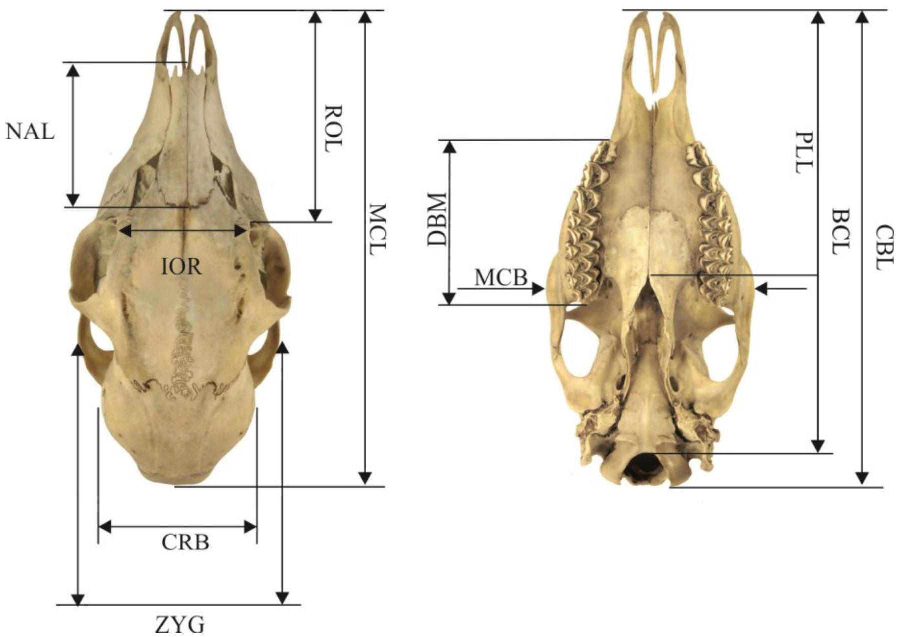

Fig. 1. The scheme of skull measurements in ungulates on the example of *Capreolus capreolus* (after Zagorodniuk 2002 with modifications).

Рис. 1. Схема вимірів черепа копитного на прикладі *Capreolus capreolus* (за: Загороднюк 2002 зі змінами).

Results and Discussion

The variation of craniometrical characters in the studied sample is shown in Table 1.

Table 1. Craniometrical characters of adult sika deer from the Askanian subpopulation, mm

Таблиця 1. Краніометричні показники дорослих оленів плямистих асканійської субпопуляції, мм

Characters	Males				Females			
	n	Mean ± SE	Min – Max	CV, %	n	Mean ± SE	Min – Max	CV, %
MCL	23	331.0 ± 1.95	315–352	2.82	20	295.7 ± 2.35	266–314	3.54
CBL	22	315.8 ± 1.61	301–331	2.39	20	284.0 ± 1.65	270–298	2.59
BCL	22	297.3 ± 1.72	282.5–314	2.72	20	265.4 ± 1.55	251.1–279	2.60
MCB	23	148.3 ± 0.77	143–158	2.48	20	122.3 ± 1.14	111–130	4.18
ZYG	22	134.5 ± 0.87	129–143.5	3.03	18	120.7 ± 0.95	111–129	3.34
IOR	23	99.9 ± 0.81	91–108	3.91	20	80.2 ± 0.79	72–86	4.44
ROL	23	184.3 ± 1.49	172–200	3.88	20	162.4 ± 1.21	155–174.5	3.35
NAL	23	115.7 ± 1.55	103–129	6.42	20	101.1 ± 1.34	92–110.5	5.94
DBM	23	90.2 ± 0.86	82.5–98.2	4.58	20	87.4 ± 1.10	78–97	5.64
CRB	22	84.9 ± 0.64	79–92	3.52	20	78.6 ± 0.69	75–87	3.96
PLL	23	186.1 ± 1.32	175–196	3.40	20	171.8 ± 1.26	161.2–181.5	3.27

Variation of characters

The analysis of craniometrical characters of sika deer revealed that nasal bones length (NAL) has the highest value of variation (CV) in both males and females. The mean value of variation by the 11 cranial characters is 3.56 ± 0.35 in males and 3.89 ± 0.33 in females.

The study of craniometrical characters by principal component analysis showed that 92.3 % of variance is described by the first principal component (PC1). The highest, though quite even, factor loadings on PC1 have characters of skull length (full length, condylobasal length, and basic length). The second principal component (PC2) describes 2.8 % of variance. The highest loadings on PC2 have such characters as maximum skull width, interorbital constriction width, and nasal bones length (Table 2). Results imply that sex-related differences in *C. nippon* by craniometrical characters are expressed by general linear dimensions and by proportions of the skull (Fig. 2).

Correlation between the characters

The correlation matrix of craniometrical characters of adult sika deer from the Askanian subpopulation shows a relatively weak dependence between different characters (Table 3). It was revealed that the correlation coefficient in most pairs of characters varies from 0.02 to 0.96 in males and from 0.01 to 0.97 in females.

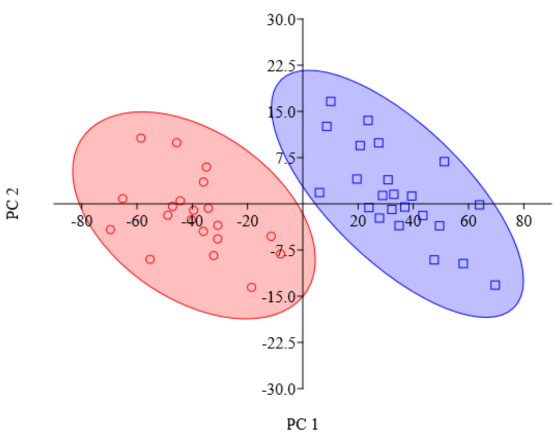

Fig. 2. Distribution of females (○) and males (□) of *Cervus nippon* in the space of the first two principal components based on craniometrical characters.

Рис. 2. Розподіл самок (○) і самців (□) *Cervus nippon* у просторі першої і другої головних компонент за краніометричними ознаками.

Table 2. Factor loadings of craniometrical characters of the sika deer on the first two principal components

Таблиця 2. Факторні навантаження краніометричних ознак оленя плямистого на перші дві головні компоненти

Character	PC 1	PC 2	Character	PC 1	PC 2
MCL	0.491	-0.308	ROL	0.307	-0.229
CBL	0.426	-0.033	NAL	0.215	-0.410
BCL	0.432	-0.002	*DBM*	0.035	0.048
MCB	0.323	0.577	CRB	0.083	-0.011
ZYG	0.180	0.319	PLL	0.212	-0.162
IOR	0.245	0.470	% of total variance	92.3 %	2.8 %

The highest values of the correlation coefficient in both males and females was revealed between CBL and BCL (respectively, $r = 0.96$ and $r = 0.97$), CBL and PLL ($r = 0.92$ and $r = 0.90$), ROL and BCL ($r = 0.88$ and $r = 0.84$), and ROL and CBL ($r = 0.87$ and $r = 0.80$). These parameters suggest the relatively highly dependent variation of these characters. Less correlated are the variation of such characters in both males and females as MCB and MCL (respectively, $r = 0.39$ and $r = 0.38$), MCB and DBM ($r = 0.26$ and $r = 0.11$), MCB and CRB ($r = 0.24$ and $r = 0.10$). Noteworthy that correlations between MCB and IOR, and MCB and ZYG are considerably higher in females than in males.

In addition, cranial proportions of adult sika deer from the Askanian subpopulation were also analysed (Table 4). It was revealed that the maximum value of variation among cranial proportions (CV) has RDBM in both males and females. The mean value of variation by the four indices of cranial proportions is 3.10 ± 0.26 in males and 2.81 ± 0.96 in females.

Table 3. Correlation of craniometrical characters of adult males (upper right corner) and females (lower left corner) of the sika deer from the Askanian subpopulation ($p < 0.05$)

Таблиця 3. Кореляція краніологічних показників черепів дорослих самців оленів плямистих асканійської субпопуляції (верхній правий кут) та самок (нижній лівий кут) ($p < 0.05$)

Characters	MCL	CBL	BCL	MCB	ZYG	IOR	ROL	NAL	DBM	CRB	PLL
MCL	**1**	0.90	0.92	0.38	0.44	0.39	0.71	0.77	0.22	0.59	0.84
CBL	0.75	**1**	0.96	0.45	0.44	0.44	0.87	0.69	0.35	0.52	0.92
BCL	0.71	0.97	**1**	0.44	0.38	0.44	0.88	0.67	0.35	0.45	0.88
MCB	0.54	0.65	0.64	**1**	0.69	0.63	0.41	0.33	0.26	0.24	0.27
ZYG	0.55	0.52	0.46	0.82	**1**	0.53	0.39	0.39	0.10	0.44	0.34
IOR	0.38	0.58	0.57	0.89	0.71	**1**	0.32	0.07	0.02	0.32	0.46
ROL	0.69	0.80	0.84	0.41	0.32	0.37	**1**	0.81	0.23	0.50	0.79
NAL	0.67	0.65	0.55	0.43	0.35	0.39	0.54	**1**	0.05	0.47	0.52
DBM	0.13	0.28	0.37	0.11	0.01	0.13	0.14	0.07	**1**	0.02	0.29
CRB	0.21	0.14	0.11	0.10	0.13	0.01	0.09	0.14	0.26	**1**	0.39
PLL	0.65	0.90	0.89	0.59	0.41	0.56	0.88	0.41	0.22	0.15	**1**

Table 4. Proportions of skulls of adult sika deer from the Askanian subpopulation

Таблиця 4. Пропорції черепів дорослих оленів плямистих асканійської субпопуляції

Proportion	Males (n = 22)			Females (n = 18)		
	Mean ± SE	SD	CV	Mean ± SE	SD	CV
RDBM	30.3 ± 0.26	1.12	3.69	32.9 ± 0.39	1.73	5.25
RMCB	50.0 ± 0.29	1.26	2.52	46.1 ± 0.33	1.50	3.25
RIOR	67.5 ± 0.42	1.90	2.81	65.6 ± 0.30	1.33	2.03
RZYG	45.3 ± 0.36	1.53	3.37	45.4 ± 0.33	1.40	0.72

Table 5. Correlation between cranial indices of adult sika deer from the Askanian subpopulation (p < 0.05): males in the upper right corner (n = 18), females in the lower left corner (n = 22)

Таблиця 5. Взаємозв'язок краніальних індексів у дорослих оленів плямистих асканійської субпопуляції (p < 0,05): самки у верхньому трикутнику (n = 18), самці у нижньому (n = 22)

Proportion index	RDBM	RMCB	RIOR	RZYG
RDBM	1	-0.19	0.11	-0.03
RMCB	0.22	1	-0.08	0.72
RIOR	-0.19	-0.16	1	-0.06
RZYG	0.13	0.72	-0.07	1

Table 6. Comparison between craniometrical characters of the sika deer from the Askanian subpopulation and the natural population from Primorsky Krai, Russia.

Таблиця 6. Результати міжпопуляційного порівняння асканійської субпопуляції та приморської природної популяції оленя плямистого

Characters	Males					Females				
	Artificial subpopulation from Askania-Nova		Natural population from Primorsky Krai***		t	Artificial subpopulation from Askania-Nova		Natural population from Primorsky Krai***		t
	n	Mean ± SE	n	Mean ± SE		n	Mean ± SE	n	Mean ± SE	
MCL	23	331.0 ± 1.95	93	305.6 ± 1.62	10.14**	20	295.7 ± 2.35	175	281.9 ± 0.69	5.61**
CBL	22	315.8 ± 1.61	95	291.8 ± 1.58	10.53**	20	284.0 ± 1.65	174	270.4 ± 0.67	7.65**
BCL	22	297.3 ± 1.72	95	273 ± 1.54	10.49**	20	265.4 ± 1.55	173	251 ± 0.68	8.55**
MCB	23	148.3 ± 0.77	105	136.9 ± 0.86	9.76**	20	122.3 ± 1.14	180	117.2 ± 0.32	4.22**
ZYG	22	134.5 ± 0.87	104	128.8 ± 0.85	4.70**	18	120.7 ± 0.95	180	114.1 ± 0.38	4.42**
ROL	23	184.3 ± 1.49	42	164.5 ± 1.92	8.17**	20	162.4 ± 1.21	96	155.1 ± 0.73	5.14**
NAL	23	115.7 ± 1.55	105	106.7 ± 0.87	4.97**	20	101.2 ± 1.34	180	96.7 ± 0.54	3.07*
DBM	23	90.2 ± 0.86	107	87.4 ± 0.44	3.16*	20	87.5 ± 1.10	181	82.4 ± 0.28	4.35**
CRB	22	84.9 ± 0.64	106	82.4 ± 0.43	3.15*	20	78.6 ± 0.69	179	75.9 ± 0.25	3.58**

Level of significance: * p < 0.01, ** p < 0.001; *** after Sheremetyev *et al.* 2004.

The correlations between cranial indices are significantly lower compared to craniometrical characters. Correlation coefficients between cranial indices of adult sika deer from the Askanian subpopulation (p < 0.05) are shown in Table 5.

The highest correlation coefficient among cranial indices is between RZYG and RMCB ($r = 0.72$) in both males and females. The least correlated indices in males are RIOR and RZYG ($r = -0.07$), whereas in females the least correlated are RZYG and RDBM ($r = -0.03$).

In order to reveal any craniological specifics, we compared the studied characters of adult sika deer from the Askanian subpopulation with those of deer from the native population from the Primosrky Krai, Russia (Sheremetyev *et* al. 2004). The analysis revealed significant differences between animals from these two populations (Table 6).

Thus, adult sika deer from the Askanian subpopulation are larger by all of the studied craniometrical characters than the animals from the natural population from the Primorsky Krai. In particular, the following characters are larger in males and females, respectively: MCL by 8.3 % and 4.9 %, CBL by 8.2 % and 5.0 %, BCL by 8.9 % and 5.7 %, MCB by 8.3 % and 4.3 %, ZYG by 4.4 % and 5.8 %, ROL by 12.0 % and 4.7 %, and NAL by 8.5 % and 4.6 %.

Conclusions

The maximum value of variation (CV) among cranial dimensions of sika deer from the Askanian subpopulation has nasal bones length in both males and females. The mean value of variation by the 11 characters analysed is 3.56 ± 0.35 in males and 3.89 ± 0.33 in females.

Males are significantly ($p < 0.001$) larger than females by all of the craniometrical characters.

Correlations between cranial indices are considerably lower than between craniometrical characters.

Adult sika deer from the Askanian subpopulation are larger than deer from the native population from the Primorsky Krai, Russia, by all of the craniometrical characters.

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References

Aramilev, V. V. 2009. Sika deer in Russia. *Sika Deer*. Springer, Tokyo, 475–499. CrossRef

Bartoš, L. 2009. Sika deer in continental Europe. *Sika Deer*. Springer, Tokyo, 573–594. CrossRef

Bromley, G. F. 1981. The sika deer (Cervus nippon Temmink, 1838) in the Primorsky Krai (former and current state of population). *In: Rare and Threatened Terrestrial Animals of the Far East of the USSR*. Vladivostok, 93–103. (In Russian)

Carden, R. F. *et al.* 2011. Distribution and range expansion of deer in Ireland. *Mammal Review*, **41** (4): 313–325. CrossRef

Cook, C. E., Y. Wang, G. A. Sensabaugh. 1999. Mitochondrial control region and cytochromebphylogeny of sika deer (Cervus nippon) and report of tandem repeats in the control region. *Molecular Phylogenetics and Evolution*, **12** (1): 47–56. CrossRef

Domnich, A. V., S. G. Okhrimenko, I. M. Svidunovich. 2014. Current state of population and ecological features of cervids under conditions of free existence within the industrial city of Zaporizhia (on Khortytsia Island). *Visnyk of Zaporizhia National University. Biological Sciences*, **1**: 47–59. (In Ukrainian)

Gulay, V. 2006. Classification of animals by the level of their adaptation to anthropogenic transformation of the environment. *In:* I. Zagorodniuk (Ed.). *Fauna in Anthropogenic Environments*. Luhansk, 14–17. (In Ukrainian)

Igratova, N. K., N. A. Chaus, V. V. Gaponov, A. Yu. Konykov. 2005. Stability of ecosystems in reserves and game husbandries if the southwest of the Primorsky Krai. *Investigated in Russia (Electronic Journal)*, No. 5283. (In Russian)

Korchagin, N. I. 2011. Fauna of the Mordovian State Reserve. *Trudy of P. G. Smidovich Mordovian State Nature Reserve*, **8**: 34–55. (In Russian)

Lowe, V. P. W., A. S. Gardiner. 1975. Hybridization between red deer (Cervus elaphus) and sika deer (Cervus nippon) with particular reference to stocks in NW England. *Journal of Zoology*, **177** (4): 553–566. CrossRef

Mirolyubov, I. I., L. P. Ryashchenko. 1948. *The Sika Deer*. Promozdata, Vladivostok, 1–116. (In Russian)

Oliger, I. M. 2016. Parasitofauna of acclimatised ungulates in the Mordovian State Reserve, 1941. *Trudy of P. G. Smidovich Mordovian State Nature Reserve*, **16**: 34–41. (In Russian)

Pérez-Espona, S., J. M. Pemberton, R. Putman. 2009. Red and sika deer in the British Isles, current management issues and management policy. *Mammalian Biology*, **74** (4): 247–262. CrossRef

Prysiazhniuk, V. E. 1981*a*. Morphometric characteristics of the aborigine sika deer of Primorye. *Zoologicheskii Zhurnal*, **60** (12): 1817–1829. (In Russian)

Prysiazhniuk, V. E. 1981*b*. Principles and issues of conservation and restoration of the wild sika deer in the Primorsky Krai. *In: Rare and Threatened Terrestrial Animals of the Far East of the USSR*. Vladivostok, 149–152. (In Russian)

Ratcliffe, P. R. 1987. Distribution and current status of sika deer, Cervus nippon, in Great Britain. *Mammal Review*, **17** (1): 39–58. CrossRef

Sheremetyev I. S., G. P. Salkina, A. S. Bogachev. 2004. Variation of craniometrical characters of the Ussuri sika deer (Cervus nippon hortulorum, Artiodactyla, Cervidae) of Primorye. *Zoologicheskii Zhurnal*, **83** (12): 1499–1507. (In Russian)

Sokolov, V. E. 1992. The European and Siberian Roe Deer: Systematics, Ecology, Behaviour, Rational Use, and Conservation. Nauka, Moscow, 1–399. (In Russian)

Swanson, G. M., R. Putman. 2009. Sika deer in the British Isles. *Sika Deer. Springer, Tokyo*, 595–614. CrossRef

Zagorodniuk, I. V. 2002. Allospecies of the roe deer (Capreolus): the nature of their differences and status of populations in Ukraine. *Visnyk of Luhansk State Pedagogical University. Biological Sciences*, No. 1 (45): 206–222. (In Ukrainian)