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ANTLER SIZE AND FORM IN RELATIONSHIP WITH CRANIAL ARCHITECTURE IN RED DEER (*CERVUS ELAPHUS L.*) A CASE STUDY IN THE CURVATURE CARPATHIANS

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Abstract: *The study has been conducted on 66 specimens of adult red deer (Cervus elaphus L.). The skulls belong to specimens harvested in the hunting season 2017-2018, but also originate from trophy collections with origin in the Curvature Carpathians. Eight trophy variables were selected for analysis, among which 13 cranial variables belong to the four cranial areas, 6 on the dorsal face, 2 on the lateral face, 2 on the ventral face and 3 on the occipital face. The sample analyzed after determining the age has been divided into 3 classes: 4-6 years, 7-9 years and over 10 years. For the investigations, a method of descriptive and multivariate statistical analysis has been used to highlight the relationships. The descriptive analysis of these variables highlighted the degree of variability of this sample, a starting point in their comparison with other populations. The analysis of correlations and regressions highlighted the links established between these variables, generating through simple and multiple regression mathematical expressions that reveal these links. The discriminant analysis performed between the three age groups highlighted the variables with discriminant value for both the cranial and trophy variables, the correct classification of the discriminant score being 85.96% per total experiment. In order to create a clearer picture of these aspects, it is necessary to study more data, especially for the category of young specimens.*

Key words: *Cervus, cranial variables, Curvature Carpathians, statistical analysis, trophy variables.*

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1. Introduction

The population of deer (*Cervus elaphus* L.) in Europe over the last 20 years has increased significantly from 1.1 to 1.7 million specimens, as well the harvest quotas, but managerial models indicate that poor administration at the level of the age classes can induce certain populations to an uncontrolled growth and, finally, to decay [3]. The deer population of Romania belongs to the subspecies *Cervus elaphus hippelaphus*, Erxl., 1877, or *Cervus elaphus montanus*, Botezat (1935) quoted by [5], and is located in the center of the area of *Cervus elaphus* L. [1], populating the chain of the Eastern, Southern and Western Carpathians and presenting important habitat fragmentation. Reduced numbers are also found in hilly and lowland areas [5]. It is considered the largest representative of subspecies in Europe, being close in size to the skull and skeleton to those of the Canadian elk deer [9].

The surface of the hunting funds in Romania that consists of the deer species, amounts to over 22 million ha, the harvest quotas of the last decade showing a significant increase in terms of numbers and population dynamics [27]. The evaluation of trophies, a historical practice, has generated over time the emergence of evaluation formulas with continuous improvements, culminating in 1930 with the establishment of the CIC, an organization that will develop new formulas with application instructions and thus eliminate non-essential aspects or subjectivism [20].

An important aspect is the fall and growth of the antlers because, every year, the males lose their horns and at about 10 days their growth begins at a speed of about 2 cm/day [4]. This process of rapid regeneration, in addition to annually determining unique individual morphologies, can bring important variations in the shape of the antlers, usually expressed by asymmetry in parts of the antlers, both numerically and morphologically [17].

The analysis of the main components (PCA) applied on 40 cranial markers of eight species of deer and aiming at the variation of the skull shape, shows that these components are closely correlated with the size of the cranial centroid but also with morphometric elements (height) and individual weight [15].

A detailed descriptive image of several physical characteristics specific to a population, is provided by cranial morphometric elements, even if genetically the epistatic implications cannot be highlighted [10, 11, 14], in general the mammalian skull being a powerful tool in biogeographic, phylogenetic and systematic studies [12], cited by Markov [13].

Last but not least, the economic aspect of obtaining valuable trophies should be mentioned as well. Knowing the population characteristics and applying a coherent management, arises in obtaining valuable trophies characterized by the size and symmetry of the antlers [19].

The present study aims to analyze the relations that are established between certain variables in the cranial architecture and variables of the trophy.

2. Material and Methods

2.1. Study Area

The study has been conducted on a number of 66 specimens of adult deer collected in the hunting season 2017-2018, as well as from private collections of trophies. Their origin is the region of the Curvature Carpathians with its respective groups, the area of the external Curvature (Figure 1) - Vrancea Mountains, Buzău Mountains, Siriului Mountains, Ciucaș Mountains, Gârbova Mountains, Bârsa Mountains, and the internal Curvature area: Bodoc Mountains, Baraolt Mountains, Breţcu Mountains, Perşani Mountains [18].

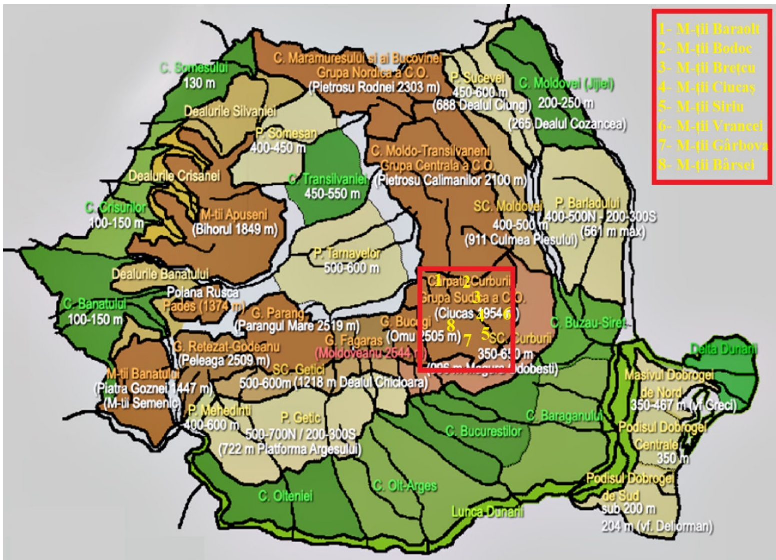

Fig. 1. *Distribution of the analyzed sample [28]*

2.2. Selection of Variables

Eight variables of the trophy have been selected, variables with high importance in its structure and evaluation (Table 1). The 13 cranial variables belong to the 4 regions, according to the model proposed by Pelabon and Breukelen [17], respectively, the dorsal region, the ventral region, the lateral region and the occipital region, being selected following the cranial architecture and the role of its bones - shape and support (Table 2), ultimately arising 21 variables that have been studied.

Because the sample contains specimens of different ages, for each of them the age was determined exactly, using the method of analysis of the secondary cement layers of the premolar I of the upper jaw [19], or mandible [21]. Following this operation, the sample was divided into three age classes: class I aged 4-6 years, class II aged 7-9 years and class III aged 10 years and over. The measurements have been performed with mechanical and electronic calipers, roulette, the accuracy being 0.1 mm for cranial variables and 1 mm for trophy variables (Appendix 1).

The cranial variables are presented in Appendix 2.

Table1

Trophy variables

No	Acronym	Explanation of the variables	Unit
1	LP	The average of main beams length	mm
2	LRO	The average of brow tines length	mm
3	LRM	The average of tray tines	mm
4	DCF	The average diameter of the front cylinder	mm
5	CR	The average circumference of coronets	mm
6	NRC	Number of tines	-
7	D_{max}	Maximum spread of beams	mm
8	D_{min}	Minimum spread of beams	mm

Table 2

Cranial variables, expressed in millimetres

No	Cranial region	Acronym	Explanation of the variables
1	Dorsal face	P-Br	Prostheon-Bregma – length of the skull from the prostheon to the point of intersection of the frontal, parietal, and occipital sutures
2		N-Br	Nasion-Bregma – length of the skull from the point of intersection of the nasal bones with the frontal bones (P) and the point of intersection of the frontal, parietal and occipital sutures (Br)
3		Fs-Fs	Frontostenion-Frontostenion – minimum width of the skull, measured at the base of the front cylinders
4		Eu-Eu	Euryon-Euryon – maximum width of the neurocranium
5		Op-Br	Opisthokranion-Bregma – length of the neurocranium, measured from the posterior extremity of the occipital bone to the point of intersection of the frontal, parietal and occipital sutures
6		P-Op	Prostheon-Opisthokranion – maximum length of the skull
7	Lateral face	Zl-P	Zygolacrimale-Prostheon – length of the viscerocranium
8		Zl-Op	Zygolacrimale-Opistohokranion – length of the neurocranium
9		N-St	Staphilyon-Nasion – viscerocranium height
10		Sph-Br	Sphenobasion-Bregma – neurocranium height
11	Occipital face	Ot - Ot	Otion-Otion – width of occipital bones
12		Con-Con	The measured width of the outer edges of the occipital condyles
13		Op - O	Opistokranion-Opistion – maximum height of the occipital face

2.3. Statistical Data Analysis

The statistical analysis has been performed using the Statistics 8 package [6. The investigation techniques used consist of the descriptive technique - mean, standard error of means, standard deviation and coefficient of variation, regression analysis and the multivariate technique - discriminant analysis. The values of these variables have been processed by means of descriptive statistical indices, and the structure and intensity of the links by means of correlation coefficient. Multiple regression analysis applied between cranial and trophy variables has been generated a series of interesting regression equations. Discriminant analysis applied to the third groups highlighted the variables with discriminant power.

3. Results

3.1. Trophy and Cranial Variables

Using the descriptive technique, the trophy and cranial variables have been processed separately on the three age classes, obtaining the main statistical indicators, respectively, mean (M), standard deviation (SD), standard mean error (Std. err. of mean) and coefficient of variation (CV%) (Table 3).

Comparing the three distributions through the coefficient of variation, the following aspects can be outlined: the LP variable for group I presents a variation of 16.5%, almost double compared to the other two groups. This variation at an early age can be attributed to the fact that the process of antlers growth is related to environmental conditions and significantly influenced by genetic variation.

The variables LRO and LRM show similar variations for groups I and III, slightly higher for group II, suggesting a strong genetic variation with rapid evolutionary syncopes for the first two groups, where the development of the defining elements of the rods is maximum, followed by a plateau.

The variables DCF and CR show for group I slightly more pronounced variations than groups II and III; these differences are determined by the genetic factor involved in the development of the antlers.

The variations of the variables NRC could be a result of a differentiated development, the genetic fingerprint being defining for the advanced ages. D_{max} shows larger variations for group I, suggesting that the rod growth process is active, whereas for the other groups it is almost complete.

D_{min} with variations of over 30% for all three groups, suggests that the genetic factor is practically responsible for the shape of the antlers and together with D_{max} define the shape of the trophy as a whole.

Regarding the cranial variables, there is a variability of less than 10%.

Suggesting a proportional, balanced development that defines cranial architecture, it can be observed in the case of these cranial elements, an accentuated variability of group I at certain bone processes as a result of ontogenetic development, also slightly more accentuated variations at groups II and III as a result of a completed ontogenetic process, these being in fact features with the help of which the so-called ecotypes can be characterized and identified, within a population.

Table3

Descriptive statistics of variables

Variable	Group I				Group II				Group III			
	M	SD	CV	Std.err.	M	SD	CV	Std.err	M	SD	CV	Std.err
LP	868,75	143,33	16,50	41,38	1070,14	71,20	6,65	12,59	1111,89	69,86	6,28	14,89
LRO	302,83	56,93	18,80	16,43	348,96	78,20	22,41	14,28	372,94	50,45	13,53	10,76
LRM	265,71	47,15	17,74	13,61	321,06	68,78	21,42	12,16	349,27	61,91	17,73	13,20
DCF	40,41	3,92	9,70	1,13	49,27	3,38	6,85	0,60	54,59	3,55	6,50	0,76
CR	194,83	31,83	16,34	9,19	245,31	22,66	9,24	4,01	252,07	19,43	7,71	4,14
NRC	4,92	1,00	20,26	0,29	7,34	1,88	25,56	0,33	9,14	2,14	23,47	0,46
D_{max}	692,50	122,00	17,62	35,22	848,91	113,26	13,34	20,02	899,55	121,50	13,51	25,90
D_{min}	478,08	145,71	30,48	42,06	595,09	183,38	30,82	32,42	600,45	230,24	38,34	49,09
P-Br	387,88	22,48	5,79	6,78	404,78	15,42	3,81	2,77	407,06	16,15	3,97	3,44
N-Br	141,83	12,55	8,85	3,62	146,55	14,57	9,94	2,57	148,94	13,22	8,88	2,82
Fs-Fs	125,00	6,01	4,80	1,73	129,48	5,99	4,63	1,06	133,09	5,86	4,40	1,25
Eu-Eu	107,82	4,98	4,62	1,44	108,91	4,27	3,92	0,75	111,09	4,78	4,30	1,02
Op-Br	97,48	7,21	7,40	2,08	100,82	7,40	7,34	1,31	103,23	10,21	9,90	2,18
P-Op	458,77	22,41	4,88	6,76	473,97	15,93	3,36	2,86	478,31	17,87	3,74	3,81
Ot-Ot	140,08	6,55	4,68	1,89	149,75	6,31	4,21	1,17	152,32	6,85	4,50	1,50
Con-Con	79,73	3,04	3,81	0,92	79,00	3,55	4,49	0,66	80,65	3,10	3,84	0,69
Op-O	63,29	3,98	6,29	1,20	64,83	4,19	6,46	0,78	66,55	6,76	10,15	1,51
Zl-P	271,67	14,69	5,41	4,43	279,75	11,72	4,19	2,11	281,70	10,97	3,89	2,34
Zl-Op	217,48	7,93	3,65	2,29	221,73	16,51	7,45	2,92	224,89	8,69	3,86	1,85
N-St	101,75	5,46	5,36	1,65	105,89	5,82	5,49	1,06	110,49	5,14	4,66	1,12
Sph-Br	105,41	4,48	4,25	1,35	108,53	4,88	4,50	0,89	112,51	4,90	4,35	1,07

Note: M - mean, SD - standard deviation, CV - coefficient of variation (%), Std.err. - standard error of mean.

Given that most of the variables analyzed show a variability of less than 30%, the sample reveals homogeneity**.**

3.2. Relationship between Trophy Variables and Cranial Architecture

The intensity of the connections between the trophy variables and those of the cranial architecture has been achieved using the simple correlation, through the simple correlation coefficient (Table 4), at a probability of transgression of 5%. The correlation matrix has been concluded for each group.

Analyzing the correlation matrix for group I, we can observe three significant positive correlations for the first variable of the trophy, for the second - two, while the third variable does not correlate with any cranial variable. The variable DCF correlates with 3 cranial variables, CR with 2, NRC with 5 variables. The diameter of D_{max} does not obtain significant correlations, and D_{min} correlates with a single cranial variable.

For the first variables of the trophy, respectively LC, LRO, DCF, the correlations with the cranial processes P-Br, Ot-Ot, Zl-Op, P-Op, can be explained using the architectural relationship and cranial symmetry necessary for the development process. For the variable CR, following the same reasoning, the symmetry points on cranial regions change. NRC, moreover, with the most connections, suggests that the weight of the trophy by summing its elements this time imprints a volumetric symmetry.

Group II shows a lower number of significant correlations between the two categories of variables. Thereby, the variable LP and D_{max} correlate with a single cranial variable, the variables LRO, LRM, DCF and CR with two variables, whilst D_{min} and NRC do not correlate with any cranial variable.

For group II, the links LP, D_{max} with Con-Con, as well as LRO with N-Br and Zl-P suggest that, at these ages, the trophy weight close to the maximum somewhat changes the center of gravity, the development of bone processes being correlated with this fact. LRM with P-Br and Sph-Br processes is based on the same reasoning. The links between DCF and CR with positioning near the Fs-Fs process can be explained by the fact that it is practically responsible for the growth and symmetry of the antlers. D_{max} and Con-Con is obviously a relationship of symmetry and balance, the Con-Con process being located at the insertion of the cervical vertebrae in the neurocranium having an essential role in support.

Group III presents an interesting situation, meaning that significant negative correlations appear between the two categories of variables. The variables LRO and LRM correlate significantly negatively with N-Br and Sph-Br, respectively D_{max} with Con-Con, and the D_{min} variable with 5 variables, respectively P-Br, P-Op, Ot-Ot, Zl-P and N-St. These negative correlations can be explained by the fact that from a certain age there is a relative withdrawal of certain cranial processes compared to the dimensions of the trophy, the averages of these processes with independent value decrease, while the averages of the trophy elements increase.

Table 4

Matrix correlation of variables by groups

Groups	Variables	P-Br	N-Br	Fs-Fs	Eu-Eu	Op-Br	P-Op	Ot-Ot	Con-Con	Op-O	Zl-P	Zl-Op	N-St	Sph-Br
I	LP	**0,698***	0,055	0,352	0,588	-0,445	0,633	**0,858***	0,022	0,065	**0,686***	0,494	0,192	0,159
	LRO	0,630	0,291	0,099	0,179	0,330	**0,745***	0,600	0,280	0,422	**0,714***	0,628	0,604	-0,036
	LRM	0,623	0,163	0,295	-0,191	0,296	0,647	0,224	0,358	0,317	0,557	0,662	0,022	0,096
	DCF	**0,730***	-0,235	0,347	0,643	-0,167	0,645	**0,670***	0,147	0,310	**0,681***	0,368	0,283	0,156
	CR	0,311	-0,334	0,321	-0,082	**0,672***	0,441	0,060	0,366	**0,910***	0,244	0,288	0,439	0,076
	NRC	**0,698***	0,059	0,362	-0,030	0,441	**0,745***	0,535	**0,761***	0,530	0,647	**0,715***	0,333	**0,718***
	D_{max}	0,407	-0,185	-0,089	0,348	0,286	0,321	-0,004	0,194	0,246	0,366	0,089	0,216	0,043
	D_{min}	0,257	-0,017	0,079	0,041	**0,865***	0,339	-0,112	0,317	0,620	0,247	0,249	0,472	-0,037
II	LP	0,311	0,294	0,135	0,256	0,059	0,323	0,297	**0,484***	0,220	0,272	0,119	0,235	0,207
	LRO	0,028	**0,492***	-0,075	0,096	-0,121	0,023	-0,161	0,022	-0,128	-0,185	**0,389***	-0,090	0,049
	LRM	**0,395***	0,244	0,089	0,249	-0,125	0,309	0,190	0,107	0,115	0,208	-0,170	0,259	**0,391***
	DCF	0,273	0,103	**0,395***	0,054	0,275	0,306	**0,392***	0,219	-0,039	0,379	-0,123	0,266	0,301
	CR	0,201	0,221	**0,506***	-0,014	0,095	0,218	0,165	0,349	-0,115	0,238	-0,148	**0,443***	0,185
	NRC	0,332	0,125	0,132	0,232	0,159	0,326	0,362	0,040	0,017	0,371	0,104	0,161	0,186
	D_{max}	0,219	0,144	-0,067	0,058	0,159	0,313	0,341	**0,393***	0,365	0,206	-0,038	0,303	0,252
	D_{min}	0,212	0,029	-0,082	0,025	-0,171	0,160	0,118	0,170	0,218	0,090	-0,099	0,277	0,301
III	LP	0,359	0,070	0,298	0,420	0,072	0,439	0,255	0,202	0,068	**0,526***	0,007	-0,103	-0,154
	LRO	-0,267	**-0,589^0**	0,000	-0,193	0,106	-0,275	0,307	0,007	-0,119	-0,300	0,054	0,078	0,125
	LRM	0,125	0,079	0,136	0,260	-0,208	0,020	-0,293	-0,039	0,141	0,138	-0,310	-0,004	**-0,497^0**
	DCF	-0,024	0,150	0,397	0,195	0,260	0,130	0,307	0,155	-0,190	0,009	0,041	-0,100	0,435
	CR	0,028	-0,129	**0,532***	0,343	**0,584***	0,323	0,412	**0,504***	-0,208	0,272	0,235	0,015	0,383
	NRC	0,405	0,213	0,353	0,381	0,127	0,390	0,028	0,230	-0,008	**0,541***	-0,087	0,365	-0,133
	D_{max}	-0,211	-0,208	0,022	-0,165	-0,184	-0,300	-0,422	**-0,456^0**	0,373	-0,234	-0,347	-0,348	-0,000
	D_{min}	**-0,494^0**	-0,252	0,113	-0,377	-0,034	**-0,513^0**	**-0,534^0**	-0,403	0,246	**-0,470^0**	-0,214	**-0,537^0**	-0,012

Note: significant coefficient of positive correlation; ^{0} significant coefficient of negative correlation; probability of transgression α = 0,05%.

Significantly positive correlations are attained between LP and Zl-P, CR and Fs-Fs, Op-Br, Con-Con, NRC and Zl-P. The variable CR positively correlated with the Fs-Fs, Op-Br and Con-Con processes, as in the case of group II can be interpreted in the same way.

The variable DCF does not correlate significantly with any cranial variable.

Another approach in investigating the association between trophy variables and cranial variables was the use of multiple linear regressions applied to the sample groups. The forward stepwise method has been used in the regression calculation, and the significance of the partial coefficients has been established for a transgression probability α = 0.05%.

For group I, a single multiple linear regression equation has been validated, respectively, between the LOR variable and the 7 cranial variables (P-Op, P-Br, Zl-P, N-St, Zl-Op, Fs-Fs and Sph-Br).

For group II, seven equations of multiple linear regression have been validated, respectively one between the variable LP and one cranial variables (Con-Con) the second between LRO and 3 cranial variables (N-Br, Zl-Op, ZlP), the third between LRM and one cranial variables (P-Br), the fourth between DCF and 2 cranial variables (Fs-Fs, Ot-Ot), the fifth between CR and 2 cranial variables (Fs-Fs, Con-Con), the sixth between NRC and 1 cranial variable (Ot-Ot) and the seventh between D_{max} and 5 cranial variables (P-Op, Con-Con, Sph-Br, Fs-Fs, P-Br).

For group III, eight equations of multiple linear regression have been validated, respectively one between the variable LP and 1 cranial variable (Zl-P), the second between LRO and 4 cranial variables (Ot-Ot, N-St, Zl-P, N-Br) the third between LRM and 1 cranial variable (Zl-P), the fourth between DCF and 1 cranial variables(N-Br), the fifth between CR and 2 cranial variables(Op-Br, Sph-Br), the sixth between NRC and 5 cranial variables(Zl-P, Fs-Fs, Con-Con, P-Op), the seventh between D_{max} 1 cranial variable(Op-O) and the eigth between D_{min} and 2 cranial variables (N-St, Ot-Ot). The regression results are presented in Table 5.

3.3. Discriminant Analysis

By applying this method of multivariate technique, an attempt has been made, a priori, to determine to what extent the trophy and cranial variables have discriminant capacity for the three groups of the sample.

In this regard, 21 variables have been introduced in the statistical model (8 trophy variables and 13 cranial variables). Of the 21 variables introduced in the model, 13 variables have been included, and 8 variables have been excluded. Of the 13 variables in the model applying statistics F and Wilks' Lambda, 6 variables have been validated (Table 6).

Discriminant functions, in this case two, have been tested for significance using the Chi square test (Table 7).

Table 5

Multiple Regession Result

Groups	Variable	Multiple R	p	The shape of the equation
I	LOR	0,9999	0,00226	LOR = - 397,19 + 4,48(P-Op) - 5,50(P-Br) + 2,58(Zl-P) - 0,78(N-St) - 0,37(Zl-Op) - 0, 30(Fs-Fs) - 0,19(Sph-Br)
II	LP	0.5567	0,0096	LP = - 95,707 + 0,531(Con-Con)
	LRO	0,7098	0,0091	LRO = 156,939 + 0,507(N-Br) + 0,480(Zl-Op) – 0,37 (Zl-P)
	LRM	0,6073	0,0103	LRM = - 204,699 + 0,942(P-Br)
	DCF	0,6260	0,0068	DCF = - 265,103 + 0,407(Fs-Fs) + 0,346(Ot-Ot)
	CR	0,6878	0,0013	CR = - 284,112 + 0,502(Fs-Fs) + 0,334(Con-Con)
	NRC	0,4099	0,0310	NRC = - 11,327 + 0,410(Ot-Ot)
	D_{max}	0,7795	0,0040	D_{max} = - 1764,023 + 2,13(P-Op) + 0,498(Con-Con) + 0,473(Sph-Br) – 0,31(Fs-Fs) – 2,10(P-Br)
III	LP	0,6081	0,0197	LP = 481,397 + 0.639(ZL-P)
	LRO	0,8852	0,0083	LRO = 367,593 +0,576(Ot-Ot) +0,599(N-St) – 0.52(Zl-P)- 0,85(N-Br)
	LRM	0,6169	0,0483	LRM = 1048,942 – 0.43(Sph-Br)
	DCF	0,8070	0,0363	DCF = -18,336 + 0,840(N-Br)
	CR	0,8070	0,0064	CR = 287,589 + 0,476(Op-Br) + 0,424(Sph-Br)
	NRC	0,8888	0,0070	NRC = - 42,157 +2,46(Zl-P) +0,897(Fs-Fs) +0,488(N-St) -0,70(Con-Con) -2,3(P-Op)
	D_{max}	0,7271	0,0415	D_{max} = 2526,602 + 0,485(Op-O)
	D_{min}	0,7251	0,0017	D_{min} = 5764,289 – 0,49(N-St) -0,49(Ot-Ot)

Table 6

The discriminant function analysis summary – bold marked values are significant

N=56	N of vars in model: 13; Grouping,3 grps, Wilks' Lambda: 10733 approx. F (26,82)=6,4728 p< 0000					
	Wilks' Lambda	Partial Lambda	F-remove	p-level	Toler.	1-Toler.
DCF	**0,1363**	**0,7872**	**5,542**	**0,0074**	**0,5095**	**0,4905**
CR	**0,1604**	**0,6690**	**10,143**	**0,0003**	**0,4570**	**0,5430**
LP	**0,1271**	**0,8446**	**3,772**	**0,0314**	**0,5856**	**0,4144**
Con-Con	**0,1285**	**0,8352**	**4,045**	**0,0249**	**0,5352**	**0,4648**
N-St	0,1209	0,8880	2,585	0,0876	0,7819	0,2181
Fs-Fs	0,1098	0,9779	0,463	0,6327	0,6583	0,3417
Zl-P	0,1217	0,8818	2,747	0,0759	0,0980	0,9020
NRC	0,1152	0,9315	1,508	0,2334	0,6943	0,3057
Ot-Ot	0,1189	0,9026	2,211	0,1224	0,4291	0,5709
Sph-Br	**0,1243**	**0,8637**	**3,236**	**0,0496**	**0,6466**	**0,3534**
P-Br	**0,1352**	**0,7940**	**5,320**	**0,0088**	**0,0477**	**0,9523**
P-Op	0,1229	0,8731	2,980	0,0619	0,0493	0,9507
Op-Br	0,1205	0,8904	2,523	0,0926	0,3107	0,6893

Table 7

Chi square test - bold marked values are significant

Function	Eigen-value	Canonical R	Wilks'Lambda	Chi-Sqr.	df	p-level
0	**3,511716**	**0,882244**	**0,107332**	**104,8959**	**26**	**0,000000**
1	**1,065042**	**0,718156**	**0,484252**	**34,0821**	**12**	**0,000655**

The determination of the degree of discrimination between the three groups, achieved by the two canonical functions, is expressed by the canonical averages of the variables (Table 8).

Analyzing the data of Table 8, it can be observed that the canonical function 1 has a discriminante value between group 1 and groups 2 and 3, the canonical function 2 having a discriminante value only between groups 1 and 3. The graphical expression of the two functions is presented in Figure 2.

Table 8

Means of canonical variables

Group	Canonical function 1	Canonical function 2
I	-4,07450	-0,47851
II	0,42302	1,01409
III	1,26245	-1,15369

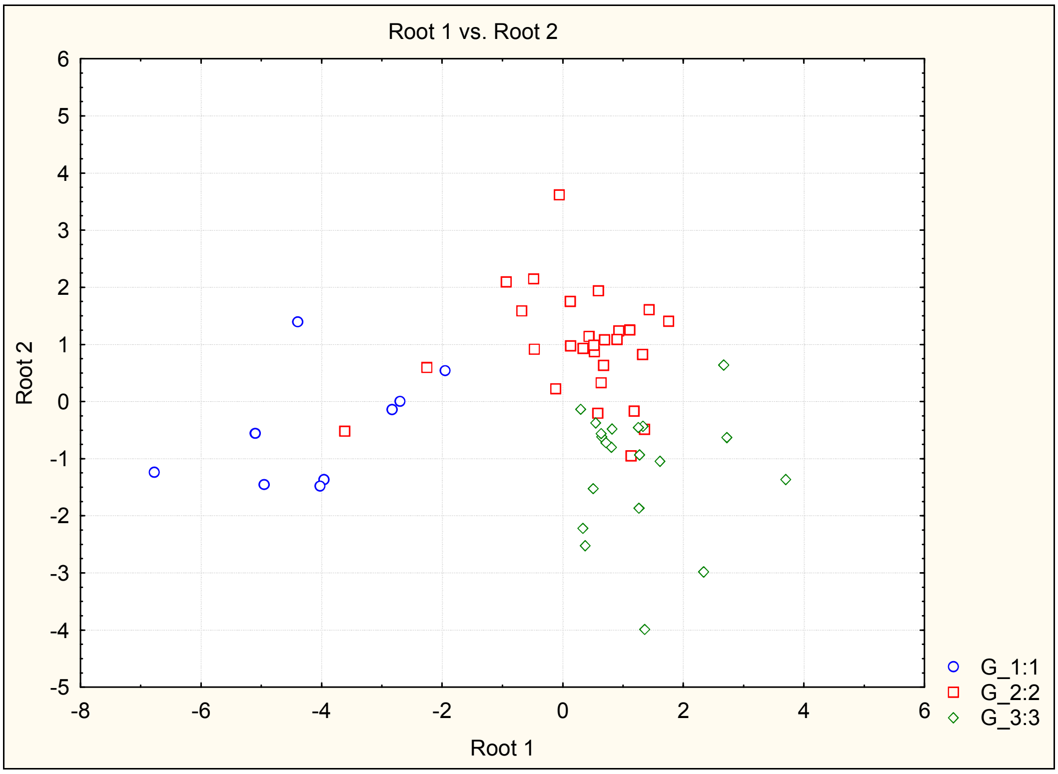

Fig. 2. *Scatterplot of canonical scores*

In regard to the probable classification, the inaccurate classification for the three groups and for the entire sample analyzed are presented in Table 9.

It can be observed that for group I the classification has been done correctly in proportion of 88.88%, out of the 9 cases one being inaccurately enclosed. In group II the classification has been done correctly in proportion of 82.14%, out of the 28 cases 5 being incorrectly classified, respectively 2 in group I and 3 in group III. In group III the classification has been done correctly in proportion of 90.00%, out of the 20 cases 2 being incorrectly classified, respectively 2 in group II. In the entire sample, the classification has been generated correctly in proportion of 85.96%.

Table 9

Observed classifications and predicted classifications

Groups	Percent correct	Gr. I p=,16071	Gr. II p=,48214	Gr. III p=,35714
I	88,88889	8	1	0
II	82,14286	2	23	3
III	90,00000	0	2	18
Total	85,96491	10	26	21

4. Discussion

The status of the subspecies and the systematic position of the deer in Romanian Carpathians is controversial topic [6]. Aspects related to morphology, weight, coat, size and characteristics of the trophy, applied in comparison to other subspecies in Western Europe, led some researchers of the time to consider that the Romanian deer population consists of two subspecies, namely *Cervus elaphus montanus* and *Cervus elaphus campestris*, (Botezat 1903) [23], more or less accepted hypotheses. Thus, a taxonomic classification specific to different authors appears - *Cervus elaphus carpathicus* (Tatarinov, 1956) [22], *Cervus vulgaris campestris* (Groves and Grubb 2011) [25], *Cervus elaphus panoniensis* (Banwell, 1997) [24]. Danilkin [7] states that the Carpathian deer is a form of transition between the Western European deer (*Cervus elaphus elaphus*) and the Caucasian deer (*Cervus elaphus maral*) [6].

The results of the genetic analyzes somewhat explain the controversies mentioned, disapproving some of the statements. In this sense, the genetic integrity of the Carpathian forms was confirmed through the distribution of the haplotype and the genetic distance [8], thus refuting the origin of the ancestral model suggested by Geist [9].

The genetic analyzes performed and, implicitly, the theories subsequently formulated, must be analyzed with caution, considering that in the IXth century and the first part of the XXth century massive populations were settled in Austria, Germany, Hungary and the Czech Republic during 1870-1918. Bradvarovic [2] with the aim of improving the quality of trophies, respectively the number of branches of the crown. Also worth mentioning are the 18 colonization centres in Romania and 3 in Serbia, where genetic material (males and females) has been distributed in almost the entire Carpathian chain, subcarpathians and certain hilly and rugged areas in the west, north-east, centre and southern Romania in the period 1960-2003 [2].

The analysis of the trophy variables reveals from the point of view of variation an interesting sedimentation at least at group level. These seemingly insignificant variations at the regional level can provide information on these characteristics, thus outlining an overview. Through the average and the coefficient of variation as statistical indicators, the trophy variables can be compared at national level, but also at European level. The same statistical indicators applied to cranial variables serve the same goals. The characterization of a population under these aspects is indicated to be performed by age classes, knowing that a simple general arithmetic mean applied to the individuals of the population can generate errors. Moreover, a further investigation on the quality and management of this population being relatively difficult to accomplish.

The correlations between the two categories of variables show that they are more numerous in the category of young deer than in the medium and large category, suggesting a link between the development of cranial bones and that of the horns, versus a stopping and the beginning of the regression of certain elements at a given time. Of course, a large number of specimens are needed for such studies, taking into account the fact that at the population level there is individual variation as an expression of genetic inheritance, on the other hand and the influence of ecological factors.

An interesting aspect compounds the regression equations obtained. It is observed that the group of young deer performs a single multiple regression equation in which 7 cranial variables are involved as explanatory factors for the LOR variable, the multiple correlation coefficient having a high significance. The other two groups perform multiple regressions between almost all trophy variables and cranial variables, thus suggesting that with age, more or less close but significant connections are made between the variables. In this context, we consider that an in-depth analysis of the cranial architecture, consisting of their regions and bones and the elements of the trophy, is necessary.

The discriminant analysis highlights three trophy variables with discriminant value between the three groups. Of these, the DCF variable according to some authors (Harke) is a criterion for determining age. The three cranial variables with discriminant value refer to the occipital area, by the size of the occipital condyles, the height of the neurocranium and the length of the skull to the intersection of the frontal, parietal and occipital bones, whose sutures, according to some authors [16], disappear with age.

5. Conclusions

Applied on a segment of 66 specimens of adult deer from the area of the Curvature Carpathians and consisting of specimens from 8 mountain ranges, this study reveals some interesting aspects regarding the relationships established between the cranial variables and those of the trophy.

The descriptive analysis of these variables highlighted the degree of variability of this sample, a starting point in their comparison with other populations. The analysis of correlations and regressions highlighted the links established between these variables, generating through simple and multiple regression mathematical expressions that reveal these links.

The discriminant analysis performed between the three age groups highlighted the variables with discriminant value for both the cranial and trophy variables, the correct classification of the discriminant score being 85.96% per total experiment.

In order to create a clearer picture of these aspects, it is necessary to study more data, especially for the category of young specimens.

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Appendix list

A1. Trophy variables

Fig. 1. *The scheme for measuring the trophy variables (original)*

A2. Cranial variables

Fig. 2. *Craniometric variables of the dorsal face (original)*

Fig. 3. *Craniometric variables of the lateral face, height of the viscerocranium (N-St) and neurocranium (Sph-Br) (original)*

Fig. 4. *Craniometric variables of the ventral face (original)*

Fig. 5. *Craniometric variables of the occipital face (original)*

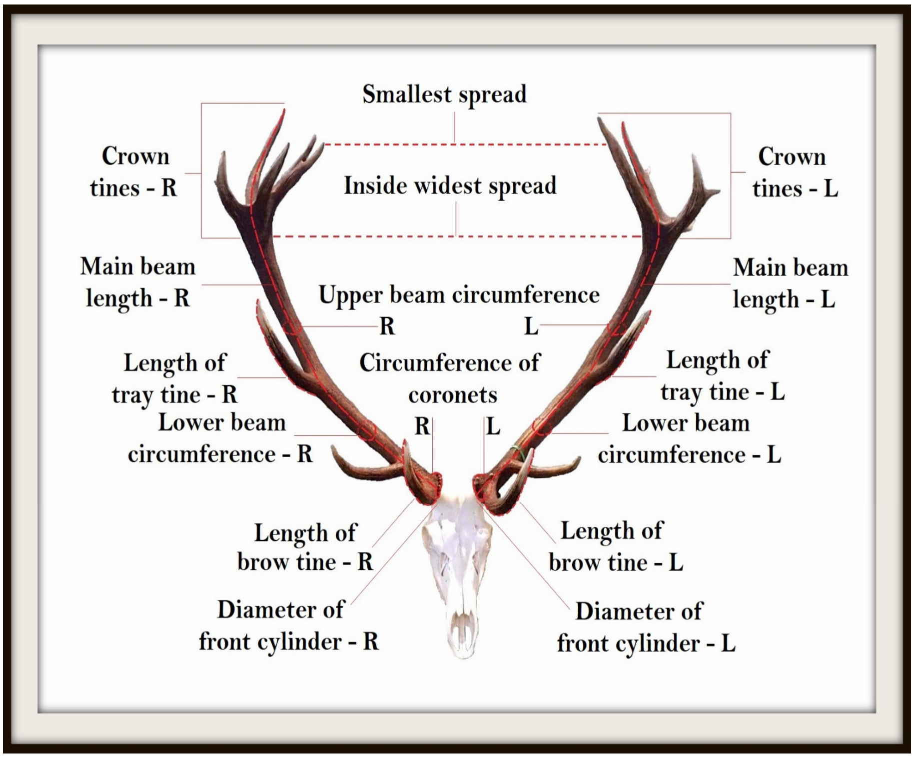

Fig. 1. *The scheme for measuring the trophy variables (original)*

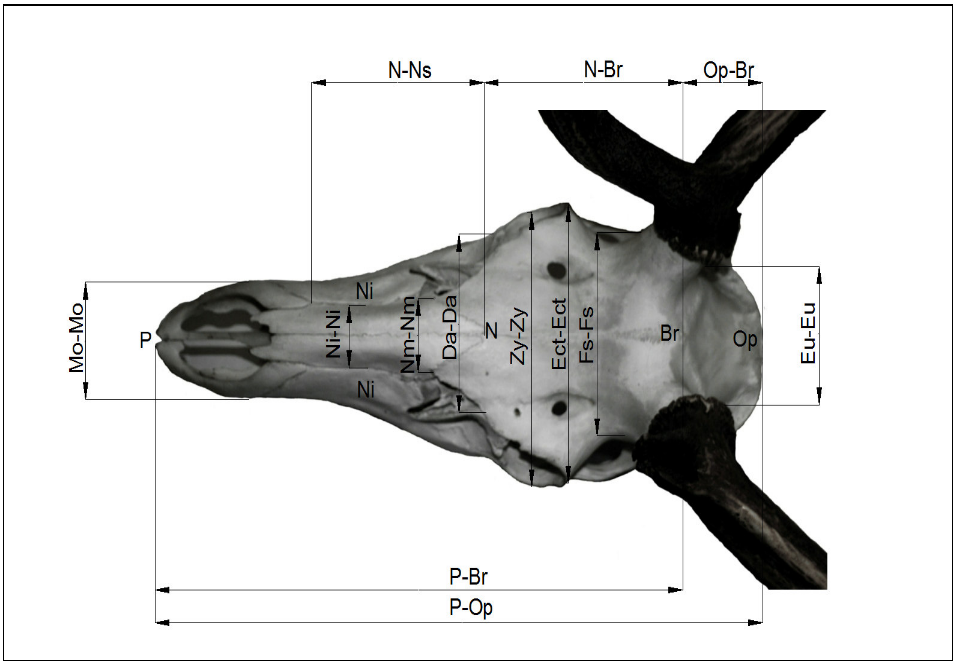

Fig. 2. *Craniometric variables of the dorsal face (original)*

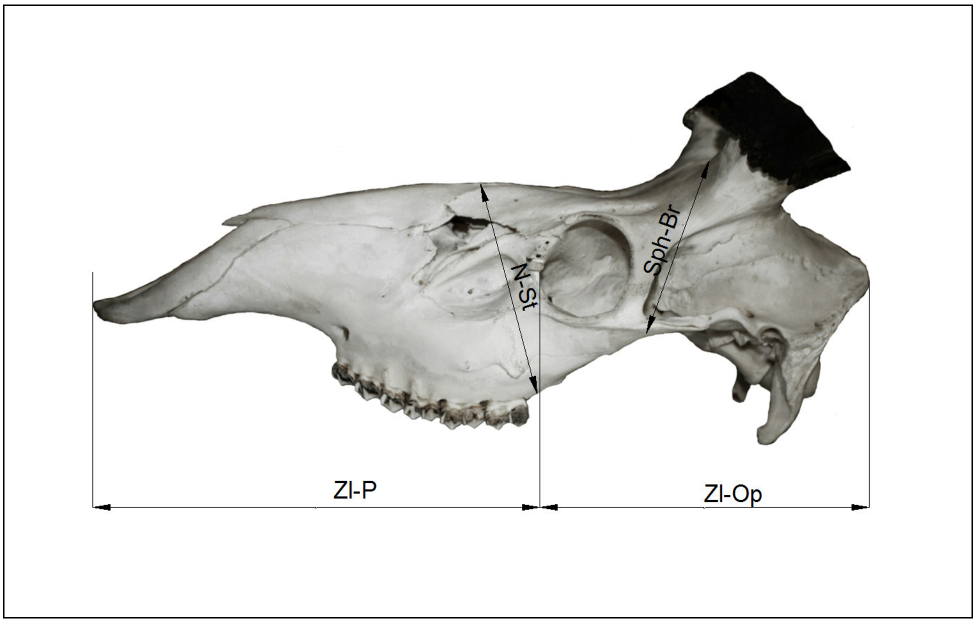

Fig. 3. *Craniometric variables of the lateral face, height of the viscerocranium (N-St) and neurocranium (Sph-Br) (original)*

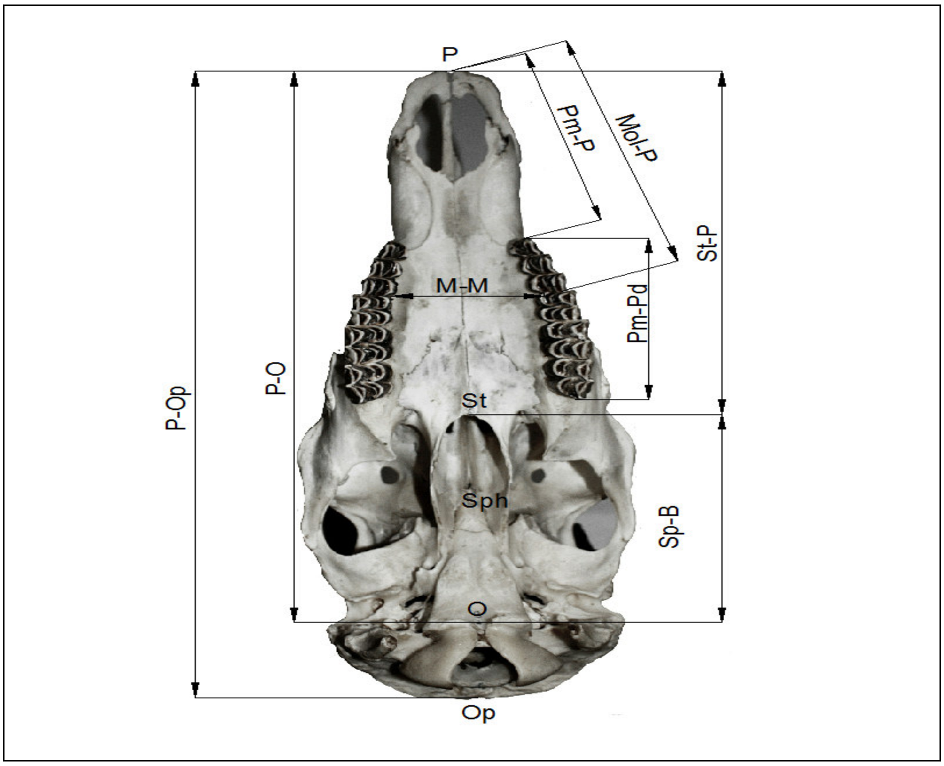

Fig. 4. *Craniometric variables of the ventral face (original)*

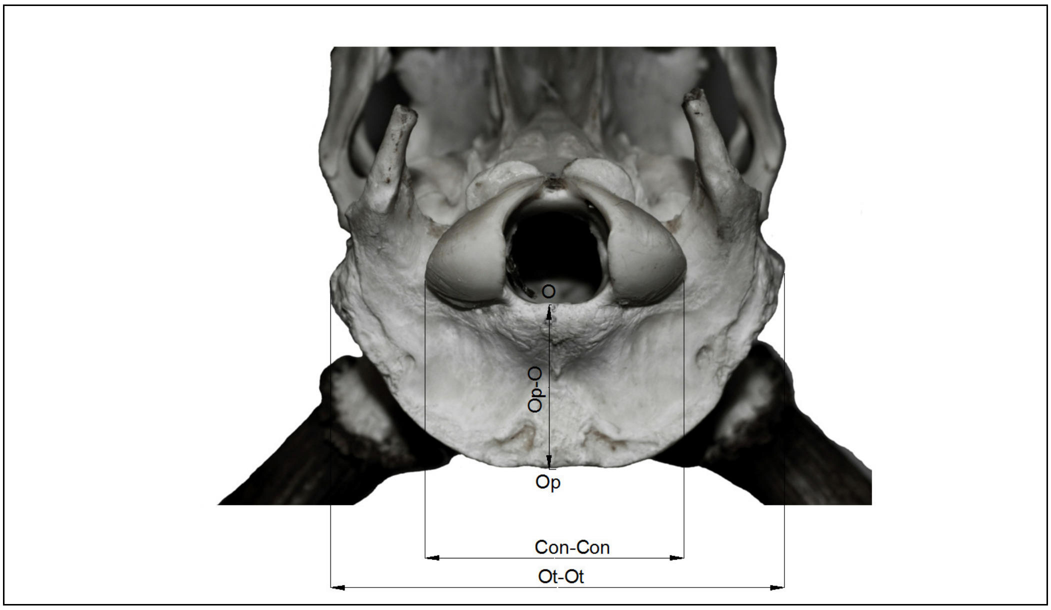

Fig. 5. *Craniometric variables of the occipital face (original)*