A COMPARATIVE STUDY ON THE VARIABILITY OF MORPHOMETRIC ELEMENTS OF THE SKULL IN CANINE SPECIES IN ROMANIA

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1. Introduction

Canids can be considered a representative family of carnivores, comprising 36 taxa, at least nine species being threatened with extinction (IUCN/SSC Canid Specialist Group, 2004).

In contrast to the several species of the family, whose development have been suffering major genetical modification, the constitution of the domestic dogs, has barely undergone any change, in other words it can be stated that from a genetic point of view, dogs are actually wolves.

The remarkable variations observed among hybrid breeds of dogs, reflect a high potential regarding the morphological changes within the canine genome (Pendragon 2011).

With a high ecological plasticity expressed by the degree of adaptation to new environmental conditions generated by the anthropogenic expansion in natural habitats, but also in naturally modified ones by the replacement of the fauna and vegetation in time, their high prolificity, this study is a challenge for the specialists on management programs.

The shape of the skull varies significantly in the members of the Carnivora order, and the determinants of their evolution and differentiation remain unclear (Slater et al 2009).

Studies were conducted on the relationship between skull shape and trophic relationships at Canidae using linear morphometric analysis and finite elements (FE), by simulating internal and external forces acting on the skull when capturing and killing prey.

After studying the ontogenetic changes of the andean fox's skull (*Lycalopex culpaeus*) in relation to feeding functions and performances at different age classes, it is concluded that the greatest differences, occur in the orbital temporal region (Segura 2013). Among the sympatric carnivores, the waist differences are particularly important in the coexistence relationship (Valkenburg and Wayne 1994), causing differences in the size of the prey, thus reducing competition. Both the quantity and quality of food cause thereby divergences of dental morphology (Valkenburg et al 1994, de Moura Bubadué et al 2016).

In some canine species, the main differences in the shape of the skull can be explained through the allometric scale relation between size and shape. The study of two species of South American foxes (*Lycalopex griseus* and *Lycalopex gymnocercus*) using 3D geometric morphometrics, in order to demonstrate that they belong to the same species, it has been shown that this is the result of the clinal variation, which is affecting the shape and size of the skull and mandible (Prevosti et al 2013).

Using 3-D modelling techniques, we compared models that exclude the size of the skull, but highlighting the relationship between shape and performance. Thus, Slater et al (2009), conclude that skull shape varies with diet and that different selective forces lead to the appearance of phenotypes and at the same time, the shape and size of the skull, as well as the strength of the bite, divide the canines into three groups, namely those specialized in the capture of small prey, intermediate ones that can be omnivorous and groups specialized in capturing large prey.

Meiri et al (2005) analyse, on a vast echelon composed of 39 species of carnivores originating from islands and continental areas, the coefficients of variation and the degree of differentiation of sexual dimorphism using the length of the skull and the maximum diameter of the canines on the jaw as working parameters to demonstrate the hypothesis of the variability of island populations. They find insignificant differences, then yielding the hypothesis that the source of variation of the continental versus island population is the gene flow.

Morphological variations of the skull in carnivores, are often studied using the geometric analysis of morphometric elements, especially to highlight the sexual dimorphism (Rezić et al 2017).

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Drake and Klingenberg (2010), by analyzing the main components (PCAs) regarding the variation of skull shape in four canine species, respectively domestic dog, coyote, wolf and jackal, observed that the domestic dog performs a limited overlap with other carnivores, moreover, variations in the shape of the skull in the domestic dog are relatively new, related to the string of skull shapes of the *Carnivora* Order taken as a whole.

Mc Carley (1962) performs a craniometry study in Arkansas, Louisiana, Oklahoma and Texas on two canine populations, respectively *Canis latrans* and *Canis niger*, in which he tests certain characters or combinations of characters, proposed by taxonomists to separate the two forms, namely: the size of the skull, the size of the canines and the spaces between the premolars, the index derived from the ratio of the palatine width to the upper jaw's molar row, the length of the posterior limb.

Comparative studies of cranial elements between the domestic dog and the maned wolf (*Chrysocyon brachyurus*), respectively 18 craniometric measurements used for the calculation of six cranial indexes, concluded that a common classification of the brachycephalic, dolichocephalic and mesaticephalic areas carried out for the domestic dog, is not validated for the maned wolf (Santos et al 2017).

In Mongolia, comparative studies of the skull morphology between two fox species, the red fox (*Vulpes vulpes*) and the corsac fox (*Vulpes corsac*), were also carried out, all of which were significantly higher, in favor of the red fox (Munkhzul et al 2018). Considerable differences were obtained by comparing domestic dog skulls, their hybrids and dingo dogs (palatine bone width, skull height, sagittal crest) (Crowther et al 2014).

The presence of the golden jackal was first reported in Romania in 1929 (Călinescu 1930). After 1980, however, their numbers grew substantially, reaching in 2002 stable populations in Southeast Romania (Angelescu 2004).

Whereas in 2007 the presence of the golden jackal has been detected on the hunting funds of 12 districts from the country, in 2018, 14,273 specimens have been evaluated, the species being reported on the entire territory of Romania, excepting the hunting funds from Suceava and Sălaj (apepaduri.gov.ro) being in a continuous process of expansion.

Another active presence is that of feral dogs, who form packs which currently populate natural habitats.

The present study analyses the morphometric elements of the skull of the three canine species native to Romania, in order to understand which of them can differentiate the skulls of certain species and to measure the impact on different prey of various taxa, as well as the implications in their management.

2. Materials and Methods

The study was based on the analysis of the skulls of golden jackals, foxes and feral dogs from the eastern and south-eastern areas of Romania, namely the counties of Vaslui, Buzău, Ialomița, Tulcea and Constanța.

The analysed samples consist of a total of 30 specimens per species (Fig. 1).

Fig. 1. Collection of golden jackal skulls (Canis aureus L. 1758), red fox skulls (Vulpes vulpes L. 1758), feral dogs skulls (Canis lupus familiaris L. 1753) (Foto L. Marfiuc)

The age of the specimens was determined using the method of analysing the wear of the superior incisors (Lombaard 1971). The samples were adult specimes, the juveniles were excluded. From 60 specimens of the wandering dog 30 skulls were chosen, whose dimensions were close to those of the golden jackals.

32 measurements of the cranial elements were performed (12 - dorsal face, 11 – ventral face, 3 – lateral face and 6 occipital face) according to the models proposed by Lynch (1996), Hartova-Nentvicova (2010), and Codrean (2012).

The elements measured on the four sides are:

» *dorsal face*: LTCr - Total length of the skull, LF - Length of the face, LNed - Length of the dorsal neurocranium, LCcd - Length of the dorsal cranium, LVi - Viscerocranial length, LON - Length of the nasal bones, LBo - Snout length, lmOr - Minimal postorbital width, lFr - Length of the forehead, lmC - Minimum skull width, lMNe - Maximum width of the neurocranium, lMZi - Maximum width of the zygomatic (skull);

» *ventral face*: LCbaz - Skull length at the basal condyles, Lcb - Basal skull length, LPa - Palatine length, lMPa - Maximum palatine width, lmPa - Minimum palatine width, lPaC - Palatine width at canine alveolae, LPr - Length of the premolar row, LMo - The length of the molar row, Lob - The length of the cheek, DBa - The maximum diameter of the hearing bubble, lCoAu - The width between the auditory ducts;

» *lateral face*: DMOr - Maximum orbital diameter, LNT - Length of transverse neurocranium, HCr - Height of the skull;

» *occipital face*: HTrOc - occipital triangle height, HFoMa - occipital hole height, lFoMa - occipital hole width, lMCoOc - maximum occipital condyle width, lMJu - maximum jugular base width, lMMa - maximum mastoid width.

For the dental canid formula I3/3, C1/1, P4/4, M2/3, 60 measurements of upper dentition and 66 lower dentition measurements were performed. For each measured teeth the height (H), the width (l) and the thickness (g) (as the arithmetic mean of the right and the left value for each tooth) were determined. The measurements were performed with an electronic calliper with 0.01mm precision.

Elements measured were characterized by three statistical indices, the mean, the standard deviation and the coefficient of variation. The description of the differences between the three canine groups was made through the discriminatory analysis in the Statistica 8 software package.

3. Results and discussion

For all measurements performed on the skull and teeth of the upper jaw and mandible, statistical distributions and dispersion, respectively arithmetic mean, standard deviation and coefficient of variation were calculated. The variation of each element measured by groups was followed, ultimately calculating the total variation of the groups (Tab. 1, Tab. 2).

Tab. 1. Statistical indices of the distribution and dispersion at skull level

Dorsal face (n = 90)			
Var	Av	Stdev	Cvar
LTCr	159.82	11.90	7.44
LF	92.27	6.72	7.28
LNed	79.10	5.66	7.16
LCcd	88.25	7.42	8.41
LVi	76.83	7.07	9.20
LON	53.47	3.95	7.38
LBo	67.78	5.15	7.59
lmOr	29.62	3.50	11.81
lFr	42.47	6.21	14.61
lmC	29.65	6.71	22.64
lMNe	53.27	4.69	8.81
lMZi	86.82	8.97	10.34
Ventral face (n = 90)			
Var	Av	Stdev	Cvar
LCbaz	152.03	10.38	6.82
Lcb	143.89	9.10	6.32
LPa	79.44	5.22	6.57
lMPa	50.89	7.69	15.12
lmPa	26.83	4.83	17.98
lPaC	28.95	4.39	15.17
LPr	43.63	3.44	7.88
LMo	17.79	1.95	10.96
Lob	57.90	3.61	6.23
DBa	21.88	2.41	11.00
lCoAu	49.89	3.66	7.33
Lateral side (n = 90)			
Var	Av	Stdev	Cvar
DMOr	28.60	2.70	9.44
LNT	86.13	6.24	7.24
HCr	55.91	5.53	9.89
Occipital face (n = 90)			
Var	Av	Stdev	Cvar
HTrOc	38.93	4.27	10.96
HFoMa	13.61	1.31	9.60
lFoMa	16.82	1.44	8.57
lMCoOc	30.11	3.32	11.02
lMJu	41.28	4.68	11.33
lMMa	50.20	4.53	9.03
Var.: variable; Av: average; Stdev: standard deviation; Cvar: coefficient of variation			

Tab. 2. Statistic distribution and dispersion indices for teeth of the upper jaw and mandible

Upper jaw (n = 90)				Mandible (n =90)			
Var	Av	Stdev	Cvar	Var	Av	Stdev	Cvar
HI1	4.98	1.26	25.35	HI1	3.66	0.84	23.01
lI1	3.43	0.83	24.11	lI1	2.26	0.46	20.44
gI1	3.95	0.86	21.66	gI1	3.10	0.60	19.36
HI2	5.85	1.45	24.84	HI2	4.26	1.04	24.46
lI2	4.12	1.03	25.10	lI2	3.02	0.72	23.79
gI2	4.41	0.96	21.81	gI2	3.77	0.77	20.39
HI3	7.58	1.71	22.49	HI3	5.85	1.28	21.80
lI3	5.12	1.30	25.50	lI3	4.20	0.87	20.70
gI3	5.13	1.01	19.74	gI3	4.21	0.79	18.70
HC	17.20	1.39	8.07	HC	15.89	1.50	9.45

IC	8.04	1.26	15.70	IC	7.85	1.24	15.81
gC	5.26	0.76	14.46	gC	5.76	0.91	15.84
HP1	4.41	0.60	13.60	HP1	3.71	0.49	13.27
lP1	4.97	0.51	10.22	lP1	3.96	0.53	13.48
gP1	3.37	0.47	13.83	gP1	3.04	0.42	13.94
HP2	5.39	0.77	14.33	HP2	5.49	0.69	12.50
lP2	8.94	0.75	8.39	lP2	8.14	0.60	7.42
gP2	3.70	0.50	13.41	gP2	3.88	0.57	14.60
HP3	5.94	0.83	14.01	HP3	5.90	0.76	12.87
lP3	10.07	0.87	8.63	lP3	9.23	0.61	6.56
gP3	4.13	0.72	17.31	gP3	4.15	0.66	15.89
HP4	9.15	1.51	16.52	HP4	7.05	0.92	13.05
lP4	16.85	1.58	9.38	lP4	10.33	0.86	8.32
gP4	8.29	1.38	16.38	gP4	5.10	0.79	15.42
HM1	6.31	1.17	18.56	HM1	10.59	1.68	15.85
lM1	11.29	1.43	12.63	lM1	18.02	2.17	12.07
gM1	14.13	1.59	11.28	gM1	7.20	0.95	13.26
HM2	3.45	0.58	16.89	HM2	4.88	0.89	18.23
lM2	6.44	0.89	13.87	lM2	7.90	0.85	10.81
gM2	9.57	1.31	13.74	gM2	6.00	0.62	10.31
				HM3	2.74	0.47	17.26
				lM3	4.02	0.80	19.99
				gM3	3.78	0.59	15.64

Var.: variable; Av: average; Stdev: standard deviation; Cvar: coefficient of variation

For the dorsal face, there is a variation of over 10% for the elements lMZi, lmC, lFr, lmOr, the smallest variation being the element LNed (Tab. 1, Fig. 2). It can be noticed that the elements with an accentuated variation are those that define the size of the skull as a whole through the bone, which is obviously related to the animal size. However, low values of the variation coefficient, below 25%, maximum for 1mC, show that the constituents are common to an average predator for all three groups.

The lmPa, lMPa, lPaC, LMo and DBa ventral face elements have variation coefficients above 10% (Tab. 1, Fig. 4). These regions of the ventral face, in addition to being related to dorsal face architecture, may suggest the type of prey approached, i.e. the ingested volume of food, lmPa with a value of 17.98%. The smallest variation is for Lob, followed by Lcb and LPa, these elements being probably those that characterize predators in general.

The lateral face reaches values below 10% of the coefficient of variation (Tab. 1, Fig. 6). However, HCr, at 9.88%, suggests that the respective region, located at the juncture of the head and neck, defines the animal size. Also, DMOr, related to the size of the skull, would influence the field of vision.

With respect to the occipital face, it is observed that the three elements HTrOc, IMCoOc and IMJu have coefficients of variation over 10% (Tab. 1, Fig. 8), the respective areas being responsible for the insertion of the spine as for the HCr element of the lateral face, thus determining the position of the head as to the neck and implicitly relative to the rest of the trunk.

The teeth of the upper and lower jaw exhibit pronounced variations in incisors and molars (25.35%, 23.01%) for all three measured elements, height (H), width (l) and thickness (g) possibly due to different wear. Values of the variation coefficient below 10%, both in the upper jaw and in the mandible, achieve the height of the canines (8.07% and 9.44% respectively) and the widths of the premolars 2, 3, and 4 (8.39%, 8.63%, 9.38% and 7.41%, 6.56% and 8.31% respectively), with lower values for the mandibular premolar widths (Tab. 2).

With a postcranial skeleton adapted for escaping and crawling (Van Valkenburgh 1985), canines rely almost exclusively on the head and teeth to hold their prey (Slater et al 2009).

The low variation in canine height between the three species can be explained by the fact that this is a common feature, canines being used for defence, killing prey and dismantling carcasses. The same reasoning can also be applied to premolars, with the indication that in this case, it is their widths.

The discriminatory analysis was performed by *separate stepwise* method for all 4 cranial faces.

For the dorsal face, the 12 component variables were introduced into the model and the *forward stepwise* method was approached. Following the analysis (Wilks' Lambda = 0.1194, F (24.152) = 51.362, p <0.0000), three of the variables, namely the maximum width of the neurocranium lMNe, the LCcd dorsal cranial lobe length and the maximal zygomatic width, had an insignificant contribution to discrimination, respectively, partial Wilks' Lambda values, 0.950, 0.972, and 0.938. Nine of the other variables had a significant contribution to discrimination, the partial Wilks' Lambda values being: minimal postorbital width lmOr 0.364; minimum width of the skull 0.673; length of the nasal bones LON 0.837; total length of the skull LTCr 0.839; total length of the dorsal neurocranium LNed 0.851; width of the forehead lFr 0.853; Snout length LBo 0.892; length of the viscerocranium LVi 0.922 and the length of the face LF 0.924.

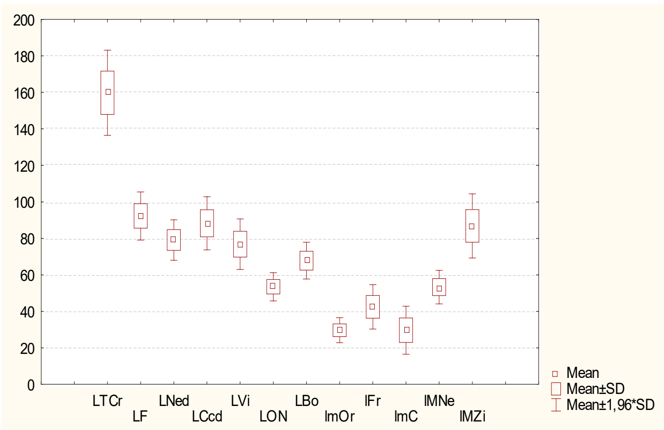

Fig. 2. The distribution of the dorsal face variables for all three groups (combined)

Canonical analysis of discrimination with two statistically significant canonical functions, χ^2=360.88, respectively χ^2=95.42 (Fig. 3) has the following averages of the canonical variables:

» for function 1, the jackal gets 3.211, the fox -6.942 and the dog 3.730.
» for function 2, the jackal gets 1.839, the fox -0.089 and the dog -1.749.

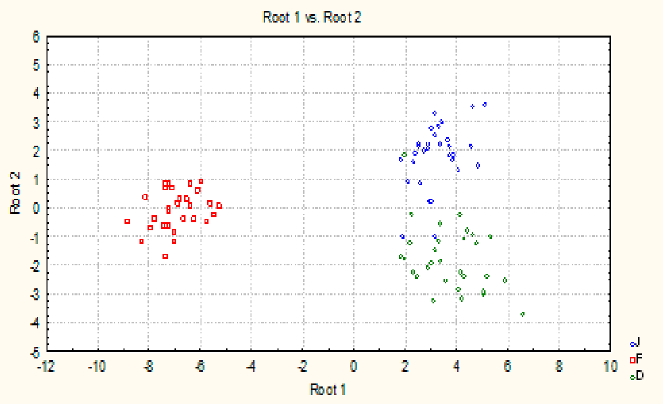

Fig. 3. Diagram of the two discriminating functions (dorsal face: J – jackal, F – fox, D - dog)

As far as classification is concerned, the discriminatory analysis correctly classified the fox with a percentage of 100%, the jackal by 93.33% (2 jackal specimens were classified as dog) and 96.66% for the dog (one dog was classified as a jackal).

For the ventral face, of the 11 variables, the Wilks' Lambda and partial Wilks' Lambda statistics excluded one of the variables, the length of the cheek Lob whose partial Wilks' Lambda value of 0.980 has an almost null discriminatory power (Mc Garigal and Cushman 2000).

Following the analysis (Wilks' Lambda = 0.01897, F (20.156) = 48.263, p <0.001), two of the variables, namely the diameter of the hearing bubble DBa with a partial Wilks' Lambda value of 0.948 and the width between the auditory channels lCoAu of 0.941, had an insignificant contribution to discrimination, the other 8 variables in the order of the discriminatory power being: the palate length LPa 0.663; maximum palatine width lMPa 0.841; skull length at basal level Lcb 0.886; palatine width at canine alveolar level laPaC 0.8985; length of the molar row LMo 0.8981; length of the premolar row LPr 0.917; skull length at basal condyles LCbaz 0.9061 and minimal palatine width lmPa 0.901.

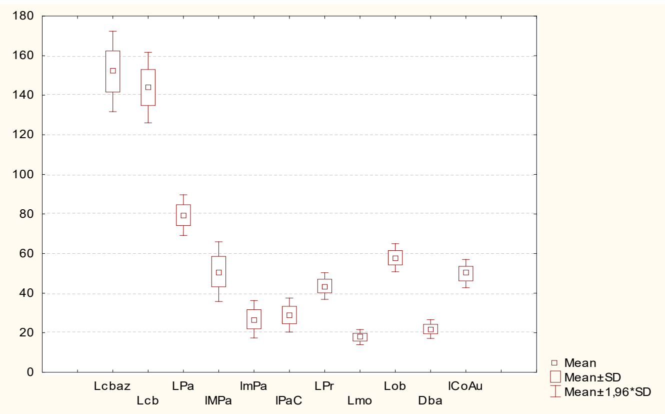

Fig. 4. The distribution of the ventral face variables for all three groups (combined)

The means of the canonical variables of the canonical analysis of the discrimination with two statistically significant canonical functions, $\chi^2 = 325.43$, respectively $\chi^2 = 112.26$ (Fig. 5) are as follows:

» for function 1, the jackal has -2.177, the fox 4.861 and the dog -2.684;
» for function 2, the jackal has -2.115, the fox 0.142 and the dog 1.973.

The first discriminating function separates the fox from the other two groups again, its canonical mean being totally different from the others. The second function acts on the other two groups.

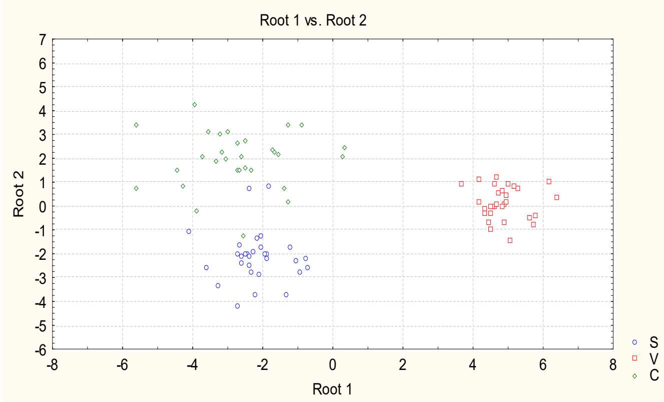

Fig. 5. Diagram of the two discriminating functions (ventral face: J – jackal, F – fox, D - dog)

As per the dorsal face, the discriminatory analysis correctly classified the fox with a percentage of 100%, the jackal by 93.33% (2 jackal specimens were classified as dog) and 96.66% for the dog (a dog was classified as a jackal). Per total groups, the correct classification was 96.66%.

For the lateral face, the Wilks' Lambda discriminatory analysis 0.967, F (6.170) = 62.761, p<0.001, the transverse neurocranial length LNT 0.963 had insignificant discriminatory power, the other two, namely the height of the skull HCr and the maximum orbital diameter DMOr, with Wilks' Lambda 0.416 and 0.544 respectively influenced the discrimination.

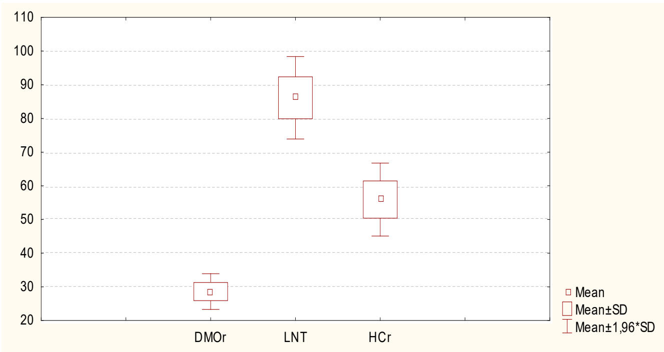

Fig. 6. The distribution of the lateral face variables for all three groups (combined)

The means of the canonical variables of the canonical analysis of the discrimination with two statistically significant canonical functions, $\chi^2 = 200.872$, respectively $\chi^2 = 69.774$ (Fig. 7) are as follows:

-for function 1, the jackal has -1.204, the fox 2.632 and the dog -1.428;

-for function 2, the jackal has 1.383, the fox -0.076 and the dog -1.307.

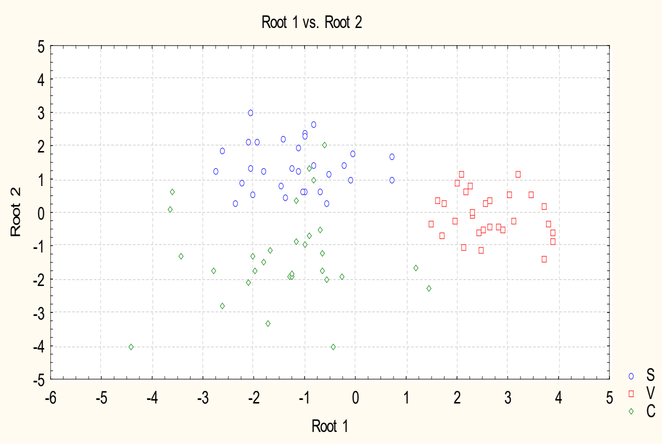

Fig. 7. Diagram of the two discriminating functions (lateral face: J – jackal, F – fox, D - dog)

In this case the discriminatory analysis again classified the fox correctly with a percentage of 100%, the jackal with 100% and the dog with 76.66% (five dogs were classified as jackals and two as foxes). Per total groups, the correct classification was 92.22%.

For the occipital face, 6 variables are introduced into the model, of which the maximum width of occipital condyles lMCoOc has an insignificant contribution. The other five elements in the order of discrimination power are: the height of the occipital triangle HTrOc, the height of the occipital hole HFoMa, the maximal mastoid width lMMa, the maximal width of the jugular base lMJu and the width of the occipital hole lFoMa.

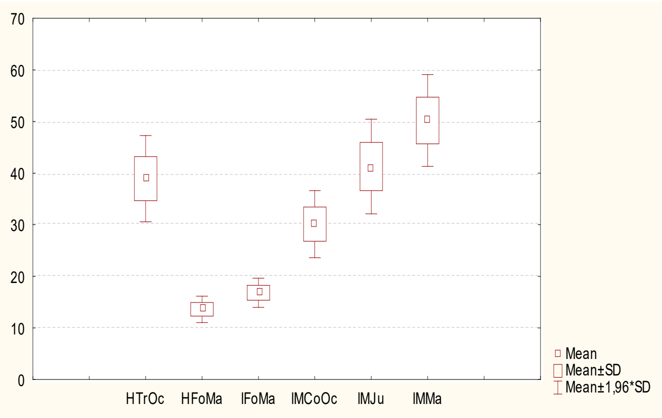

Fig. 8. The distribution of the occipital face variables for all three groups (combined)

The means of the canonical variables of the canonical analysis of the discrimination with two statistically significant canonical functions, χ^2 = 209.537 respectively χ^2 = 45.810 (Fig. 9) are as follows:

» for function 1, the jackal has -1.485, the fox 3,381 and the dog -1.896;

» for function 2, the jackal has 1.060, the fox -0,083 and the dog -0.978.

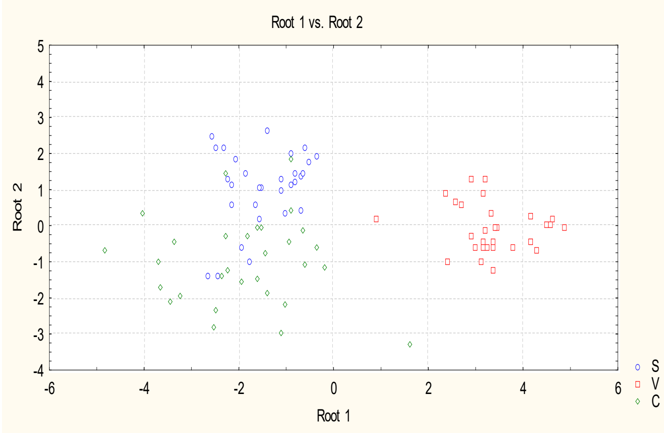

Fig. 9. Diagram of the two discriminating functions (occipital face: J – jackal, F – fox, D - dog)

In this case, the discriminatory analysis again classified the fox with a percentage of 100%, the jackal with 86.66% (4 jackals were classified as dogs) and the dog with 83.33% (4 dogs were classified as jackals and one as fox). Per total groups, the correct classification was 90.00%.

For the upper jaw dentition, of the 30 variables analysed, only 20 of them made it in to the Wilks' Lambda model = 0.00841, F (40.136) = 33.673, p<0.0001, due to their very limited discrimination power. Of the 20 variables in the model, only 11 have significant discriminatory power.

The means of the canonical variables of the canonical analysis of the discrimination with two statistically significant canonical functions, χ^2 = 370.313 respectively χ^2 = 123.607 (Fig. 10) are as follows:

» for function 1, the jackal has 2.735, the fox -6,652 and the dog 3.916;

» for function 2, the jackal has -2.515, the fox 0.281 and the dog 2.234.

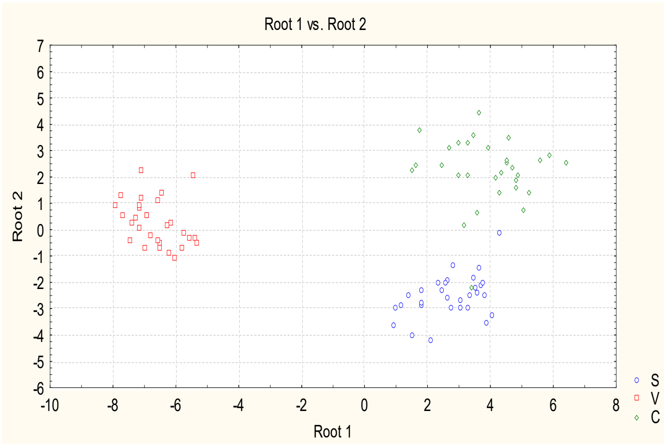

Fig. 10. Diagram of the two discriminating functions (upper jaw dentition; J – jackal, F – fox, D - dog)

The discriminatory analysis again correctly classified the fox with 100%, the jackal with 96.66% (one jackal was classified as dog), the dog with 96.66% (one dog was classified as jackal). Per total groups, the correct classification was 97.77%.

For the lower jaw dentition, of the 33 variables analysed, only 22 of them made it in to the Wilks' Lambda model = 0.1489, F (44.136) = 21.588, p<0.0001, due to their very limited discrimination power. Of the 22 variables in the model, only 9 have significant discriminatory power.

Canonical analysis of discrimination with two statistically significant canonical functions, χ^2 = 321.85, respectively χ^2 = 109.69 (Fig. 11) has the following averages of the canonical variables:

» for function 1, the jackal has 1.317, the fox -5.183 and the dog 3.866;
» for function 2, the jackal has 2.410, the fox -0.679 and the dog -1.731.

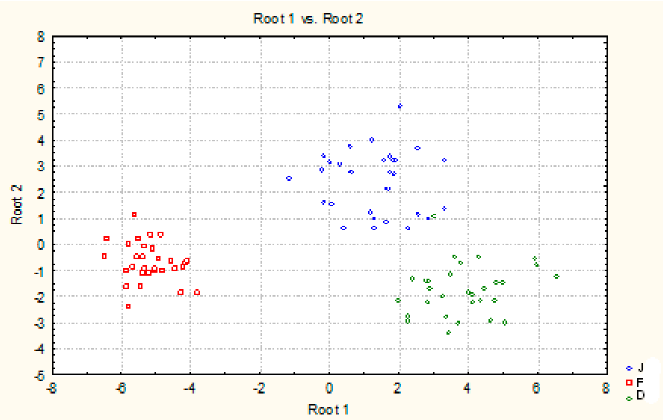

Fig. 11. Diagram of the two discriminating functions (lower jaw dentition; J – jackal, F – fox, D - dog)

The discriminatory analysis correctly classified the fox with 100%, the jackal with 100%, the dog with 96.66% (one dog was classified as jackal). Per total groups, the correct classification was 98.89%.

4. Conclusions

The comparative study of the variability of the morphometric elements for the three canine species, performed on the 4 cranial faces, reveals a moderate variation of the constituent elements, the samples presenting a convenient homogeneity. However, somewhat more pronounced variations were found in the dorsal, ventral and occipital face variables, which define the skull architecture as a whole, relative to the animal size.

Elements of the lateral face with values below 10% of the variation coefficient suggest that the shape of the skull is typical of a medium-sized predator with common traits of feeding.

The upper jaw and mandible teeth have pronounced variations in incisors and molars, with possible implications for the type of prey approached.

The discriminatory analysis done by the *forward-stepwise* method allowed the selection of the most significant elements. Thus, for the dorsal face with 12 variables in the model, 9 are significant, 96.66%, for the ventral face with 11 variables in the model, 8 are significant with an average of classification of 96.66%, for the lateral side with 3 variables in the model, 2 are significant, the average of classification is 92.22%, for the occipital face with 6 variables in the model of which 5 significant, with an average of classification of 90.00%, for the upper jaw dentition with 30 variables in the model, 11 are significant with an average of classification of 97.77% and for the lower jaw dentition with 33 variables in the model, 9 are significant with an average of classification of 98.89%.

The results obtained through the discriminatory analysis are satisfactory in terms of classification, but for further study we consider that it is necessary to study other cranial elements with similar features, as well as performing a comparative analysis based on the same principles of subpopulations throughout Romania.

In any case, the fox occupies a visible and secured separate position, compared to the golden jackal and the dog, adapted to other type of smaller prey, as is well known.

There is a partial overlap between the golden jackal and the common dog regarding bone structure and dentition, that proves that they can prey on the same spectrum of animals.

Along with the wolf, with which there are sympatric species, there is a possible competition for food and habitat. As a result, new management plans for canine species in Romania are needed.

References

Angelescu A, 2004. The Golden Jackal. MMC Publ. House, Bucharest.

Călinescu R, 1930. Schakale in Rumänien. *Zeitschr. f. Säugetierk*. Berlin V6: 373-375.

Codrean C, 2012. Research on the fox population in Barsa Country. Transilvania University of Brasov.

Crowther MS, Fillios M, Colman N, Letnic M, 2014. An updated description of the Australian dingo (*Canis dingo* Meyer, 1793). *Journal of Zoology*, 293 (3): 192-203.

de Moura Bubadué J, Cáceres N, dos Santos Carvalho R, Sponchiado J, Passaro F, Saggese F, Mondanaro A, Raia P, Carotenuto F, 2016. Character displacement under influence of Bergmann's rule in *Cerdocyon thous* (Mammalia: Canidae). *Hystrix, the Italian Journal of Mammology*, 27 (2): 83-90.

Drake AG, Klingenberg CP, 2010. Large-Scale Diversification of Skull Shape in Domestic Dogs: Disparity and Modularity. *The American Naturalist*, 175: 289-301.

Hartova-Nentvicova M, 2010. Sexual dimorphism of cranial measurements in the red fox (*Vulpes vulpes*) from the Czech Republic. *Folia zoologica* 59: 285-294.

Lynch JM, 1996. Sexual dimorphism in cranial size and shape amongred fox (*Vulpes vulpes*) from nord-east Ireland. Proceedings of the Royal Irish Academy, Dublin, 98B/1: 21-26.

Lombaard D, 1971. Age determination and growth curves in the black-backed jackal. *Annales Transvaal Museum*, 27: 135-169.

Mc Carley H 1962. The Taxonomic Status of Wild Canis (Canidae) in the South Central United States. *Southwestern Association of Naturalists*, 7(3-4): 227-235.

Mc Garigal K, Cushman S, 2000. Multivariate Statistics for Wildlife and Ecology Research. Springer, 155-175.

Meiri S, Dayan T, Simberloff D, 2005. Variability and correlations in carnivore crania and dentition. *Functional Ecology* 19: 337-343.

Meiri S, Dayan T, Simberloff D, 2005. Variability and sexual size dimorphism in carnivores: Testing the niche variation hypothesis. *Ecology* 86(6): 1432-1440.

Munkhzul T, Reading RP, Buuveibaatar B, Murdoch JD, 2018. Comparative craniometric measurements of two sympatric species of *Vulpes* in Ikh Nart Nature Reserve, Mongolia. *Mongolian Journal of Biological Sciences*, 16 (1): 19-28.

Pendragon B, 2011. A review of selected features of the family Canidae with reference to its fundamental taxonomic status. *Journal of creation*, 25 (3): 79-88.

Prevosti FJ, Segura V, Cassini G, Martin G, 2013. Revision of the systematic status of Patagonian and pampean gray foxes (Canidae: *Lycalopex griseus* and *L. gymnocercus*) using 3D geometric morphometrics. *Mastozoologia Neotropical*, 20(2): 289-300.

Rezić A, Bošković I, Lubinu P, Piria M, Florijančić T, Scandura M, Šprem N, 2017. Dimorphism in the Skull Form of Golden Jackals (*Canis aureus* Linnaeus, 1758) in the Western Balkans: A Geometric Morphometric Approach. *Pakistan J. Zool.,* 49 (3): 989-997.

Santos ALQ, Paz BF, Barros RF, Nalla SF, Pereira TS, 2017. Craniometria em lobos-guará *Chrysocyon brachyurus* Illiger, 1815 (Carnivora, Canidae). *Ciênc. anim. bras*, 18: 1-9.

Segura V, 2013. Skull ontogeny of *Lycalopex culpaeus* (Carnivora: Canidae): description of cranial traits and craniofacial sutures. *Mammalia*, 77(2): 205-214.

Slater GJ, Dumont ER, Van Valkenburgh B, 2009. Implications of predatory specialization for cranial form and function in canids. *Journal of Zoology* 278: 181-188.

Van Valkenburgh B, 1987. Skeletal indicators of locomotor behavior in living and extinct carnivores. *Journal of Vertebrate Paleontology*, 7 (2): 162-182.

Van Valkenburgh B, Wayne RK, 1994. Shape divergence associated with size convergence in sympatric east African Jackals. *Ecology*, 75 (6): 1567-1581.

IUCN/SSC Canid Specialist Group, 2004. Canids: Foxes, Wolves, Jackals and Dogs.

***Statistica 8, Stat Soft, Inc, 1984 -2004.

www.apepaduri.gov.ro.

Abstract

The craniometric study was carried out on three canine species from Romania, namely the golden jackal, the fox and the feral dog. The specimens of golden jackals and foxes belong to the hunting grounds of south-eastern Romania. The analysed specimens of feral dogs were taken from the same hunting grounds as well as from hunting grounds of Vaslui County.

The analysed craniometric elements focused on the four cranial faces, namely the dorsal face, the ventral face, the lateral face and the occipital face, as well as elements of the jaw, mandible and teeth.

The working method consisted in investigating the statistical parameters of distributions and dispersion of analysed elements.

Forward stepwise discriminatory analysis highlighted the discriminatory elements of the three species, with classification accuracy of 100% for foxes, 95% for golden jackals and 91% for free-ranging dogs.

Key words: *Canis aureus*, *Vulpes vulpes*, *Canis lupus familiaris*, canonical functions, discriminatory analysis.