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Study of the variability of red deer (*Cervus elaphus* L.) populations in the Carpathian Mountains

ABSTRACT

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Foreword

The red deer (*Cervus elaphus* L.) is an important species in the ecological conditions of Romania, both in terms of its range and its importance in the management of hunting grounds.

Achieving valuable trophies from this species depends largely on how well the gene pool and seasonal conditions of the habitats concerned are managed and administered effectively.

Examination of the skull and trophy through its morphometric elements and their interaction with environmental factors can provide important information on the ecology, ethology of the species and aspects related to the pathology of the animal.

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Introduction

The red deer (*Cervus elaphus* L.) is a game species of important economic and hunting value. A widely distributed species in Europe, its population has increased in the last 20 years from 1.1 to 1.7 million (Barbosa et al., 2009), but is suffering from range contraction, fragmentation and in some regions even extinction (Bertouille, De Crambrugghe, 1985). Archaeozoological studies on the Carpathian deer population have hypothesized that this population is a transitional form between the Western European deer (*Cervus elaphus elaphus*) and the Caucasian deer (*Cervus elaphus maral*) (Danilkin, 1999; Croitor, 2015). Controversies regarding the origin and genetic forms of the Carpathian range deer have been explained by the presence, haplotype distribution and genetic distances existing in this range (Feulner, Bielfeldt, Zachos, 2004).

However, these results and theories must be viewed and interpreted with reservations given that in the 9th century and the first part of the 20th century (between 1870 and 1918), massive stocking with specimens from Austria, Germany, Hungary and the Czech Republic (Bradvarovic, 2017) was carried out in order to improve the quality of the trophy through hybridization, especially to increase the number of rays in the crown. Subsequent to these repopulations, between 1960 and 2003, through 18 colonisation centres in Romania and Serbia, the genetic material (males and females) was distributed in almost all the Carpathian range, Subcarpathians and some hill areas in western, north-eastern, central and southern Romania (Bradvarovic, 2017).

The cranial morphology of the species is relatively little studied or carried out on a small number of specimens, with studies taking into account especially the trophy as a necessity for their evaluation and classification (Sîrbu et al., 2022).

Variation in skull shape through its elements achieves significant correlations with morphometric elements that influence animal height and weight (Flueck, 2020), with certain characteristics of a population being provided by morphological elements of the skull even if genetically, epistatic effects do not highlight them (Geist, 1998; Janiszewski et al., 2011). These cranial elements are important and powerful tools for biogeographic, phylogenetic and systematics studies (Lovari et al., 2008; Baker, Hoelzel, 2013). Ecological factors, diet diversity and relative diet hardness can influence cranial variation (Loy, 2007), body mass and mandible size are also significant indices of habitat quality (Markov, 2014), morphocraniometric and trophic analyses can also provide a detailed descriptive picture of population characteristics (Geist, 1998; Janiszewski, Kolasa, 2006). These aspects validate hypotheses related to the interaction of genetic diversity and phenotypic expression and resulting in some significant asymmetric fluctuations (Mattioli, Ferretti, 2014), revealing at individual level also some osteopathological lesions in the palatal bones (Merino et al, 2005).

Geometric, morphometric methods (3D Landmarks) applied on different deer species have suggested that biotope, through its elements related to food quality and variety, strongly influences craniomandibular shape and size (Mattioli, Ferretti, 2014). Changes induced by foraging behavior on the shape and size of some anatomical elements can be notable in contrast to phylogenetic elements, suggesting a high correspondence between a fundamental niche and a subsequently acquired one (Mystowska, 1966).

A characteristic feature of cervid species is the shedding of antlers each year followed by very rapid growth (Pélabon, van Breukelen, 1998), this regeneration process resulting in a unique, individual morphology and bringing important variations in antlers, sometimes through a symmetry/asymmetry of crown and poles, both numerically and spatially (Sîrbu et al., 2020). Taking into account the above mentioned aspects, this paper proposes to analyse the variability of deer samples from three relatively different areas of the Carpathians in terms of habitat and altitude, namely the Eastern Carpathians, the Curvature Carpathians and the Southern Carpathians. Comparative analysis of cranial and trophy elements from these areas, through the prism of variability, promotes the hypothesis of important variations that may generate ecotypes within the Romanian deer population.

Chapter 1. Current state of knowledge on the origin, evolution, biology, ecology, ethology and variability of the red deer (*Cervus elaphus* L.)

1.1. Origin and evolution of the deer.

The red deer, (*Cervus elaphus* L.) known in Romania under the popular name of Carpathian deer, common deer (Cotta, Bodea, Micu, 2001) is part of the Cervidae family whose evolution is estimated at over 30 million years. Occupying habitats from the tropics to the tundra, between desert and forest, it can be considered the most evolutionarily and adaptively successful family of mammals (Geist, 1998).

Harrington, (1985), cited by Geist (1998), notes that the ancestral Eurasian cervids, respectively, have a low and relatively stable diversity compared to those that have arisen by radiation in other areas. This increased diversity appears to be the result of a complex process of speciation. For the sake of relative simplicity, it can be accepted taxonomically that there are two tribes within the subfamily Cervinae - Cervini (true deer) with the four genera *Axis*, *Dama*, *Rucervus* and *Cervus,* and Muntiacini.

The origin of the deer is linked to the existence of three ancestral lines: the line that populated the highlands of western China, eastern Tibet and the foothills of the Himalayan chain, the line that populated western Europe and Asia Minor (also called "long-tailed" deer) and the line that radiated to the cold lands, namely the elk. (Geist, 1998).

1.1.1 Systematic framing

Comprising populations of the same origin, taxonomically the family Cervidae is divided into three subfamilies: Capriolinae with its best known representatives, namely caribou (*Rangifer tarandus*), elk (*Alces alces*), roe deer (*Capreolus capreolus*) and other relatives; Cervinae with its best known representatives deer (*Cervus elaphus* L.), wapiti (*Cervus elaphus canadensis*) and twenty other subspecies, the mule deer (*Dama dama*) and Japanese deer (*Cervus nippon*); Hidropotinae with a single representative, the Chinese waterbuck (*Hidropotes inermis*) (Animal Diversity Web, 2017).

Geist (1998) separates the European deer into two main lines: the East European and the West European deer and considers them as subspecies. Studies of cytochrome b protein variability in three deer populations in Hungary revealed three distinct mitochondrial lineages: the western lineage (A), the eastern lineage (C) specific to European species (Ludt et. al, 2004, Skog et. al., 2009) and lineage (B) restricted to North Africa, Sardinia, Italy (Zachos, Hartl, 2011) and Bulgaria (Markov et. al., 2011), cited by (Markov, Kuznetsova, Danilkin, Kholodova, Sugar, Heltai, 2015).

Systematic species classification (after Vertebrate Zoology, 1983 with additions, Animal Diversity Web, 2017) is as follows:

Reggnum Animalia
Vertebrate Encirclement
Gnathostoma subbranch
Supraclass Tetrapoda
Class Mammalia
Subclass Theria
Infraclass Eutheria
Order Artiodactyla
Suborder Ruminantia (Selenodontia)
Family Cervidae
Subfamily Cervinae
Genus *Cervus*
Species *Cervus elaphus* L., 1758

1.1.2. Caryotype

The karyotype and its evolution can provide important data on the evolutionary course of a species (Gustavsson and Sundt, 1967). Matthey (1964), cited by Gustavsson and Sundt (1967), states that between 53% and 70% of the mammals of the infraclass Eutheria studied have a diploid number of chromosomes with values between 40 and 56. The number of chromosomes of species inhabiting areas with a cold climate is higher than in temperate or warm climates (Geist, 1998). Thus, the Eurasian species adapted to extreme climates, the sika deer (*Cervus nippon*), the Hokaido Island hound deer (*Dama dama*), the Tibetan deer *(Cervus albirostris*), have a chromosome number of 2n=68 and 2n=66 (Wang et al., 1982), respectively, while the southern, tropical forms (sika deer in southern areas, 2n=64; sambar (*Cervus unicolor*), 2n= 60; mountain deer (*Cervus elaphodus, Cervus reevesi*) with 2n=47, respectively, 2n= 46. Deer (*Cervus elaphus L.*) have a diploid number of chromosomes, i.e. 2n=68.

1.1.3. Subspecies and hybrids

As with species taxonomy, there is much controversy about the number of subspecies taxa. IUCN (2018), after the latest investigations, has established a number of 9 subspecies of the Eurasian deer, namely: *Cervus elaphus hippelaphus* populating western and central Europe including the Balkans, *Cervus elaphus maral* with habitat in Asia Minor, Crimea, the Caucasus region and northwest Iran, *Cervus elaphus atlanticus* in the Scandinavian Peninsula, Norway, *Cervus elaphus scoticus* in Scotland and England, *Cervus elaphus hispanicus* in the Iberian Peninsula, *Cervus elaphus corsicanus* in Corsica and Sardinia, *Cervus elaphus bactrianus* in Afghanistan, Kazakhstan, Kyrgyzstan, Turkmenistan, Uzbekistan and Tajikistan, *Cervus elaphus yarkandensis* in Xinjang, China, *Cervus elaphus barbarus* in Algeria, Tunisia and Morocco.

Cervus elaphus hippelaphus

Cervus elaphus maral (Gray 1850)

Cervus elaphus atlanticus

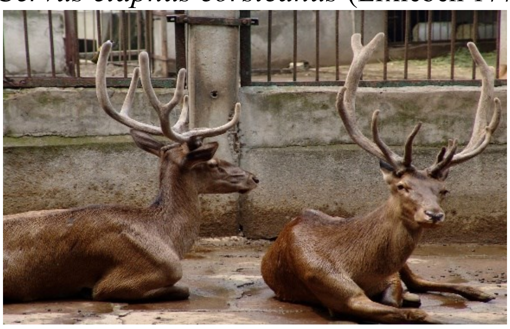
Cervus elaphus scoticus

Fig. 2a. - Eurasian subspecies of the deer (source, Wikipedia)

Cervus elaphus hispanicus

Cervus elaphus corsicanus (Erxleben 1777)

Cervus elaphus bactrianus (Lydekker, 1900)



Cervus elaphus yarkandensis

Fig. 2b. - Eurasian subspecies of deer (source, Wikipedia)

As far as hybrids of deer species are concerned, an important issue is their origin, natural or artificial. Hybridisation can have major effects on the genetic structure of a native population through the phenomenon of genetic introgression (Biedrzycka, Solarz, Okarma, 2012). Hybrids between European deer and elk, for example, are not very viable under natural conditions, (Pearse, 1991) cited by Geist (1998) indicating that offspring from mating European deer females with elk males are larger in size, leading to birth difficulties.

Natural hybrids between European and Sika deer occur in many locations in Europe (Iceland, UK), East Asia, New Zealand, many of which are also found in captivity, with fertile offspring.
(www.macroevolution.net/mammalia-hybrids.html)

Very rare in the wild, hybrids between Pere David's (*Elephorus davidsoamus*) and Eurasian red deer (*Cervus elaphus* L.) occur in the UK.

1.1.4. Deer range in Europe.

According to the latest reports on deer populations in Europe, 35 countries have native or reintroduced deer from native populations (Burbaite, Csanyi, 2010). Native deer occur in Armenia, Austria, Belarus, Belgium, Bosnia, Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, France, Georgia, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Macedonia, Serbia, Moldova, Montenegro, Netherlands, Norway, Poland, Romania, Russian Federation (European part), Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, Turkey (European part), (Lovari et al., 2008, in IUCN Red List of Threatened Species). Isolated subpopulations are reported in Greece as a result of reintroductions; also in Portugal where, in addition to reintroductions, there has been cross-border expansion from Spain. Extinct from Albania (Lovari et al., 2008, in IUCN Red List of Threatened Species).

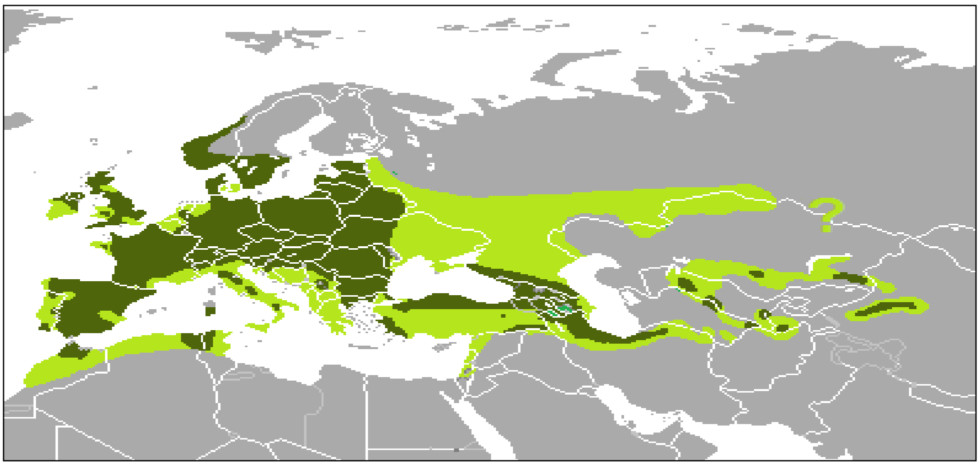


Fig. 3. Distribution of red deer (*Cervus elaphus* L.) in Eurasia (light green for reconstructed distribution, dark green for current distribution). (Source Wikipedia, File: Red deer (Cervus elaphus) reconstructed and recent.png.)

In the last 20 years the European deer population has increased significantly from 1.1 to 1.7 million, i.e. an increase of 52.99%, harvest quotas from 275 thousand to 492 thousand, i.e. 55.76% (Burbaite, Csanyi, 2010). The rate of population growth in Eastern and Central Europe is not correlated in some countries with that of harvest quotas. The lack of information on population structure suggests that large deer populations are very difficult to control.

1.1.5. Deer range in Romania

Located at the eastern end of the range of the subspecies *Cervus elaphus hippelaphus* Erxl., 1777, also called *Cervus elaphus montanus* Botezat (1935), (Heptner et al., 1966, cited by Cotta, Bodea, Micu, 2001), the Romanian deer population is practically in the centre of the range of *Cervus elaphus* L., 1758 (Almășan, Ilie, Scărlătescu, 1977), showing important habitat fragmentation.

The defining ecological conditions in population fragmentation are linked to the size and distribution of forest areas, but also to the anthropogenic factor with its expressions (road networks, railways, urban agglomerations).

In Romania, the deer inhabit the Eastern and Southern Carpathians, from Maramures to Oltenia, continuing with the Western Carpathians. Reduced numbers can also be found in the hilly and lowland areas (Cotta, Bodea, Micu, 2001).

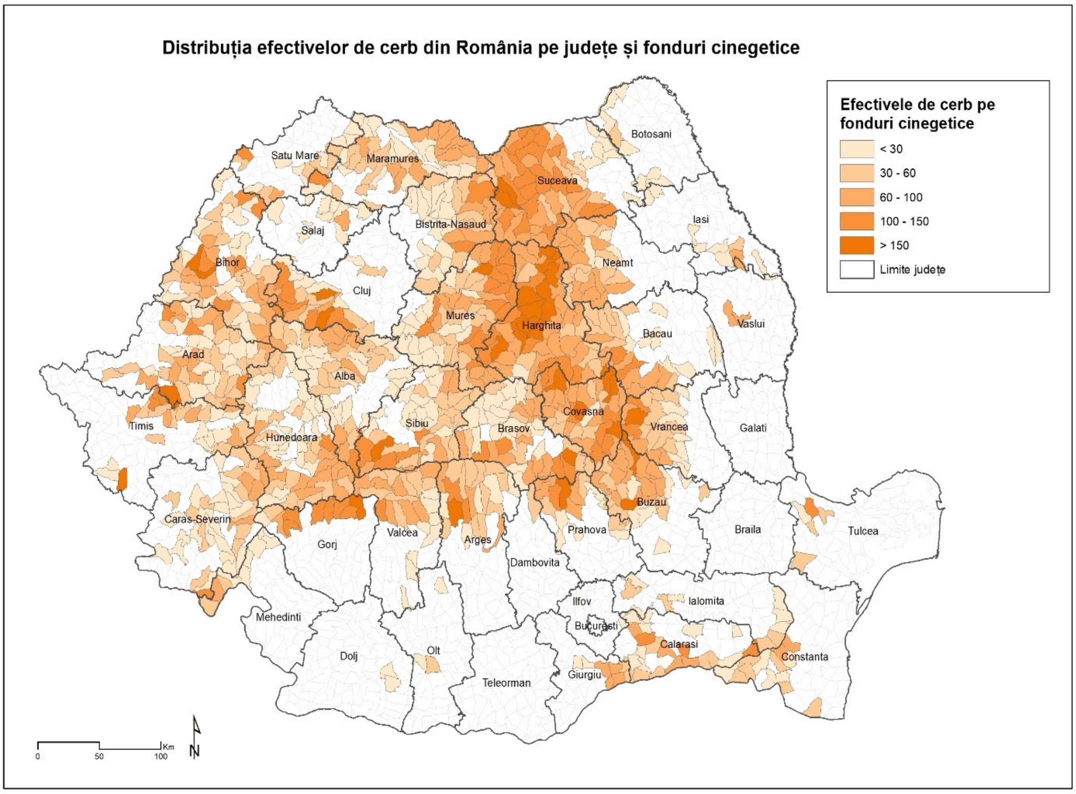


Fig. 4. Deer distribution in Romania, source: INCDS "Marin Drăcea" 2022, Brasov.

In terms of population dynamics (Fig. 5), the assessment of the deer population between 2006 and 2022 shows an increase from about 36098 to 50920.

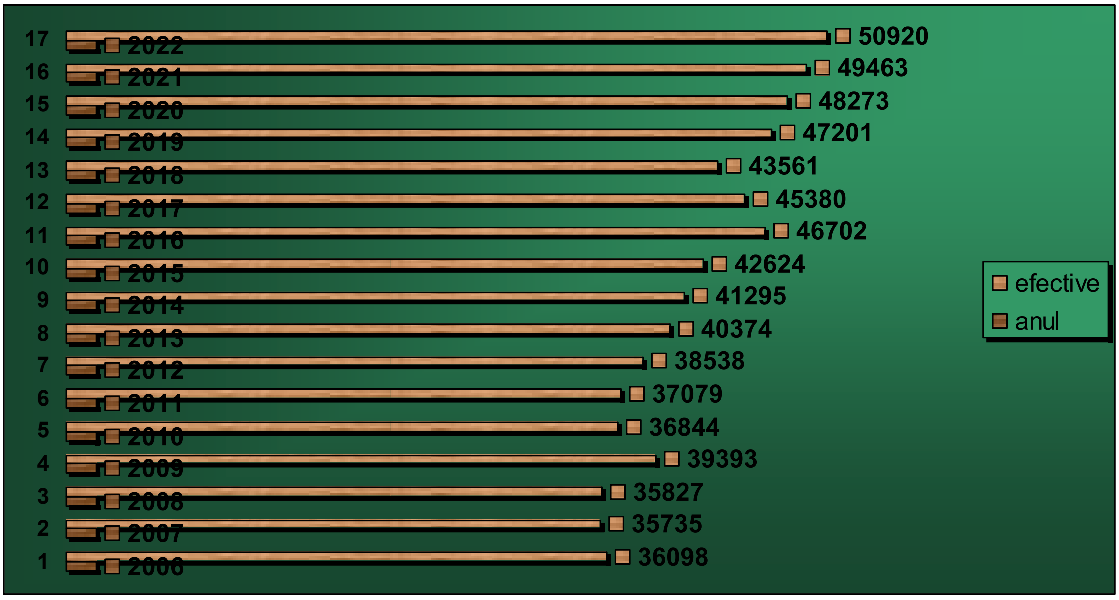


Fig. 5. Deer herd dynamics in Romania between 2006 and 2022

1.2. Deer biology

1.2.1. Morphology

The subspecies *Cervus elaphus hippelaphus* (Almășan, Ilie, Scărlătescu, 1977), called the Carpathian deer or common deer, inhabits the territory of Romania and is considered the largest representative of the species in Europe. It is close in cranial and skeletal dimensions to the Canadian wapiti deer (Szaniawski, 1966, cited by Geist, 1998).

1.2.2. Weight

In Romania, body weights vary according to age, season and feeding conditions. The average weight of males is 240-250 kg live and 210 kg eviscerated. Female calves have an average weight of 80 - 130 kg, calving calves weighing between 7 and 12 kg (Cotta, Bodea, Micu, 2001; Negruțiu, 1983).

1.2.3. Hairs

The color of the deer presents two forms due to the two periods of rutting, respectively, spring and autumn, with certain gaps between individuals, the determining factor being age. The calf, in the first 3 months, presents the phenomenon of homochromy represented by light spots all over the body that mimic the sun's rays penetrating through the foliage of the tree, as a means of defense against predators (Cotta, Bodea, Micu, 2001).

1.2.4. Dentition. Age assessment of deer.

Characteristic of deer is the lack of incisors on the upper jaw, the area being replaced by muscular and cartilaginous tissues that grip and break food.

The deer tooth has two phases, namely: the milk tooth phase with formula i0/3 c1/1 pm3/3 and the permanent dentition with the formula I0/3 C1/1 PM3/3 M3/3 (Brown, Chapman, 1991).

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An accurate method of determining the age of the deer, and in fact the most accurate, is to analyse the dentine layers of the first pair of incisors. It is a cumbersome method, requiring the tooth to be subsequently sectioned and ground (Cotta, Bodea, Micu, 2001). Age determination using this method involves counting the layers of dentin deposited up to the pulp of the tooth, plus three years.

1.2.5. Sexual dimorphism. Growth and development of horns.

In the family Cervidae, sexual dimorphism is manifested by body mass size, the existence of horns in males (Clutton - Brock, 1982; Carranza, 2004; Garde et.al., 2010, cited by Salmeron, 2014) with the exception of caribou (*Rangifer farandus*) in which the female also bears horns, the shape and structure of the coat, appearing as a curvilinear function on habitat variation (Geist, Bayer, 1988).

Depending on the number of branches, their positioning on the pole, the existence or absence of a crown, the antlers are given different names: spear deer, fork deer, six, eight, ten, twelve deer, as well as the inserted branches: eye branch, ice branch, middle branch, wolf branch, crown (Cotta, Bodea, Micu, 2001).

1.2.6. Reproduction and gestation

The rutting season for red deer is between 10 September and 10 October, slightly earlier on the plains where the temperature is higher. Depending on the temperature, the period can be shifted from normal dates (Cotta, Bodea, Micu, 2001).

The sexual maturity of males capable of reproduction is 5-6 years, but males as young as 3-4 years can also mate (Cotta, Bodea, Micu, 2001).

1.2.7. Sex ratio. Longevity. Mortality

The normal numerical sex ratio is 1:1, at most 1:1.5 in favour of females. If this ratio were to change in favour of females, the consequences would be overbreeding, exceeding the optimum herd size, reduced body weight and horn weight, followed by a deterioration in the quality of the herd because there is no competition between bulls, so that weak animals could also participate in the breeding.

In terms of mortality, infant mortality is of particular interest.

1.3. Pathology

The diagnosis of diseases of game animals, as well as domestic animals, is based on the establishment of elements of etopathology that can be used as criteria for identifying diseases.

With regard to the sources of pathogens, it is important to point out that there are two categories of etiological factors, namely: transmissible etiological factors, viruses, bacteria, protozoa, mice, helminths, in which transmission is from a sick animal to a healthy one, with or without multiplication in the body, and non-transmissible etiological factors, usually abiotic, heavy metals, pesticides, radiation, atmospheric factors, endogenous factors, etc. of the type of immunopathies, organopathies, with an intrinsic etiology (Secașiu, Puchianu, 2012).

1.3.1. Virotic diseases

1.3.1.1 Rabies

It occurs sporadically and is caused by the virus being inoculated into the body through bites. It is externalised by severe central nervous system disorders, excitability, paresis and paralysis ending in death. The disease agent is a virus of the *Rhabdoviridae* family with affinity for nerve cells. The symptomatology of the deer is characterised by loss of the fear instinct, i.e. flight, where the animal approaches residences.

1.3.1.2 Aujeszski's disease

It is common to several species of domestic and wild mammals, including deer. Pseudorabies, as it is also called, is caused by an Alphaherpesvirus, a member of the Herpesviridae family, and the course of the disease is acute, with a clinical picture predominantly of nervous disorders and pruritus (Secașiu, Puchianu, 2012).

1.3.1.3 West Nile Virus Encephalitis

It is produced by a single-stranded RNA virus transmitted mainly by arthropods.

1.3.2 Bacterial diseases

1.3.2.1 Anthrax

Infectious disease common to animals and humans, produced by *Bacillus anthracis,* with sporadic or endemic evolution and characterized clinically by acute evolution, fever, circulatory and respiratory disorders, and morphopathologically by hemorrhagic diathesis, serohemorrhagic edema, hypertrophy and spleen softening (Secașiu, Puchianu, 2012).

1.3.2.2 Brucellosis

An infectious disease caused by germs of the genus *Brucella,* affecting various domestic and wild species including humans, with sporadic-endemic occurrence and chronic evolution.

1.3.2.3 Leptospirosis

It is produced by germs of the genus *Leptospira*, with endemic-epidemic evolution, inapparent clinically or manifest. Infection is transmitted transcutaneously or via the oral, pharyngeal, conjunctival mucosa.

1.3.2.4 Tuberculosis

Infectocontagious disease produced by germs of the genus *Mycobacterium*, with sporadic-endemic character, characterized by a chronic evolution with polymorphic and non-specific symptoms, and morphopathologically by specific proliferative or exudative lesions in various tissues and organs (Secașiu, Puchianu, 2012).

1.3.2.5 Pasteurellosis

It is an infectious disease with sporadic-endemic character and acute and chronic evolution, caused by several species of *Pasteurella*.

1.3.3 Parasitic diseases

1.3.3.1 Coccidiosis

They are protozoonoses produced by sporozoans of the order *Coccidia,* genera *Eimeria* and *Isospora*, in deer and deerhound *E. cervi*, *E. austriaca, E. asymmetrica*, *E. robusta* (Nesterov, 1984). They are intracellular parasites that are localized in the intestine, liver, kidneys, with sexual and asexual propagation. It is common to all species of game, and is of particular mortality concern to captive animals.

1.3.3.2 Fasciolosis (big goiter)

It is a helminthosis with hepatic localization, with chronic evolution and is manifested by disturbances of general metabolism, weakness and cachexia (Nesterov, 1984). It is influenced by factors such as environmental temperature, pasture humidity and the existence of biotope suitable for intermediate hosts.

1.3.3.3 Cestodesis

The aetiological agents for deer, roe deer and red deer species are *Moniezia expansa* and *M. Benedeni*, parasites with a body length greater than 4 m. They are one of the parasitoses that act negatively in antler formation and quality, as well as in bone strengthening.

1.3.3.4 Nematodes

Nematodes can be located in the respiratory tract with the parasitic agent in ruminant game represented by *Dictyocaulus viviparus*, causing the disease called metastrongylosis or verminous bronchopneumonia.

1.3.4. Diseases caused by mites

1.3.4.1 Ixodide mites

The etiological agents are the ticks *Ixodes ricinus*, *Dermacentor marginatus*. Signs of attack are intense itching and restlessness. As a result of intense scratching, the hair around the tick's attachment site appears ragged, broken and dirty. Parasites in all forms (larvae, nymphs, adults) take up large quantities of blood for food, causing anaemia, weakness and debilitation, which are particularly evident in the young (Nesterov, 1984). They are also dangerous to game as vectors of infection.

1.3.5 Diseases caused by insects

1.3.5.1 Haematopoiesis

Hematopoiesis, or anoplure insect attack, is caused by species with limited activity. The aetiological agent parasitising deer is *Solenopotes burmeister*.

1.3.5.2 Malofagosis

Malophagous ectoparasites live in the fur of mammals and use hair debris and sloughed skin cells as food. In deer, ectoparasites are caused by *Rhabdopelidon longicornis*.

1.3.5.3 Oestriosis

Parasitosis caused by the larvae of various insect species of the subfamily *Oestrinae*, with localization and development in the nasal cavities and sinuses, as well as in the pharyngo-laryngeal cavity.

1.3.5.4 Hypodermosis

It is a subcutaneous connective tissue meiasis produced by larvae of various species of the *Hypodermatidae* family, manifested by subcutaneous nodules in the dorsolumbar region.

1.3.6 Prion diseases

1.3.6.1. Chronic wasting disease of cervids

It is a prion disease caused by unconventional transmissible agents, with a slow progression characterized clinically by progressive weakening, behavioural disorders, paralysis followed by death, and histopathologically by degeneration of the pericardium, neuropil spongiosis and astrogliosis (Secașiu, Puchianu, 2012).

1.3.7. Non-specific (medical) diseases

The most frequent in cervids are thermal congestion and pneumonia, caused by external factors (winds, heavy snow cover, limited food sources). Dental abnormalities with excessive elongation or shrinkage of teeth can be caused by trauma, hormonal and mineral metabolism disturbances during growth.

Excessive hoof growth with movement difficulties is due to excess horn as a result of habituation of the animals on soft soils lacking a stony layer.

1.4. Deer ecology

In addition to the notion of habitat of a species, it is important to specify the term station of a species as a part of the habitat used limited according to needs and often having a temporal character, i.e. seasonal characteristics (Naumov, 1961). In this sense the deer, by its behaviour, is one of the species that uses different habitats, seasonally, as a result of the vegetation succession but also of the management of the stands, resulting from anthropic activities (Comșia, 1961).

1.4.1 Abiotic factors

The climatic factor is the most important, determining in addition to the horizontal distribution (latitude and longitude) a vertical distribution of the species given by altitude (Comșia, 1961). Latitudinal, seasonal and inter-annual variation in the climatic regime can influence the reproductive process, morphology and distribution of the species (Albon, Clutton-Brock, Langvatn, 1992).

1.4.2 Biotic factors

The biotic influencing factors of the species relate to habitat, diet, intraspecific relationships and interspecific relationships.

1.4.2.1. Habitat

Characteristic of the deer in terms of the habitat used is its polytypism, the animal being present depending on the season in several habitats, i.e. alpine and subalpine with the border forests, the area of mixed deciduous and coniferous forests.

1.4.2.2. Diet

The diet of a species is the key element in determining its habitat (Straus, 1981). It should be noted that the diet of deer varies significantly according to the growing season and the quality of the habitat. Diet identification is quite difficult and in this respect micro-histological analysis provides important and precise information.

1.4.2.3. Intraspecific relationships

Intraspecific relationships through bonds and interaction determine the population structure of a species, the way it uses its habitat and not least its way of life (solitary, gregarious, colonial), with changes following certain rules depending on the season. (Naumov, 1961).

1.4.2.4. Interspecific relationships

Interspecific relationships take many forms and relate to competition between sympatric herbivore species on the one hand and predation species on the other hand, as a result of interaction with species-specific predator populations.

1.5. Anthropogenic factor

Human activity has a significant influence on deer populations worldwide. These influences can have negative aspects (reduction of territories, hunting, tourism, grazing, introduction of competing species), but they can also have a positive side expressed through certain management measures aimed at improving the survival and health of a population to some extent (supplementary feeding during difficult periods of the cold season, reduction of excessive predator pressure).

1.6. Deer ethology

By knowing the elements, generically called bioelements with a relatively unchanging character, with a constant value of a species (Comșia, 1961) and which directly or indirectly influence the individual activity and then the whole, represented by the population, it is possible to build patterns for each species, which temporally and cyclically follow certain laws characteristic of individuals in a community, giving rise to individual behaviour, expressed through the deer's activities.

1.6.1. Feeding behaviour

A herbivorous animal, deer eat a variety of herbaceous plants, tree leaves and lilies in the spring-autumn period and lichens, lilies, tree bark, and wall and raspberry dewings in the winter. Depending on the availability of this food and the season the animal chooses its resting place, usually as close as possible to these areas. Feeding takes place in the evening and at night, making it a night and dusk animal, retreating to its resting places in the morning. In quiet areas it also feeds during the day (Cotta, Bodea, Micu, 2001).

1.6.2. Social and territorial behaviour

Over a period of about 10 months per year, deer exhibit gregarious social behaviour formed by groups of different ages, followed by a short period of time corresponding to the rutting period (September - October) when these groups split up developing sexual behaviour influenced by intense hormonal activity (Lincoln, et. al., 1972).

1.6.3. Breeding behaviour

In the deer species, breeding behaviour takes on spectacular forms, especially during the peak period (15 September - 15 October). These periods can be delayed, depending on the weather, with temperature being the determining factor.

As for males, studies show that they lose weight substantially, differentially, i.e. senescent specimens show greater losses than young ones, the causes being based on the hypothesis that the old ones would enter the rut in a state of poor maintenance, the density of individuals being also correlated with this phenomenon (Yoccoz, et. al., 2002).

Chapter 2. Aim and objectives of the research

2.1. Purpose of the Research

The aim of the research is to determine the ecotypes of the common deer (Cervus elaphus L.) population in the Romanian Carpathians, i.e. the Eastern Carpathians, the Curvature Carpathians and the Southern Carpathians, through a comparative analysis of the variability of cranial and trophy elements.

Research objectives

1. Morpho-anatomical analysis of biological material for sampling and stratification of samples from the three regions studied, variation of cranial indices;

2. Multicriteria descriptive statistical analysis of cranial and trophy elements from the three samples;

3. Correlative analysis of cranial architecture and trophy as component parts;

4. Comparative analysis of the three samples in terms of age group and interpopulation variability using the multivariate statistical technique.

Chapter 3. Place of research. The material and method of work.

According to the geographical regionalization, the samples analyzed belong to the central unit of the Romanian Carpathians and the Inner Plateau of Transylvania, some specimens also belong to the extra-Carpathian units, namely, the Subcarpathians of Moldavia, the Curvature Subcarpathians, the Transylvanian Subcarpathians and the Getic Subcarpathians.

The hunting grounds from which the study material has been collected, have been used as reference territorial units.

In the Eastern Carpathians, measurements were carried out in Suceava county with 23 hunting grounds, Harghita county with 16 hunting grounds, Neamţ county with 7 hunting grounds and Bacău county with 5 hunting grounds, for a total of 62 hunting grounds.

Within the Curvature Carpathians, measurements were carried out in the counties of Covasna with 14 hunting grounds, Braşov with 15 hunting grounds, Buzău with 9 hunting grounds, Vrancea with 5 hunting grounds and Prahova with 5 hunting grounds, for a total of 47 hunting grounds.

In the Southern Carpathians, measurements were carried out in the counties of Braşov with 5 hunting grounds, Brasov with 15 hunting grounds, Argeş with 10 hunting grounds, Hunedoara with 16 hunting grounds, Sibiu with 10 hunting grounds, Vâlcea with 5 hunting grounds, Alba with 3 hunting grounds and Gorj with 1 hunting ground, for a total of 50 hunting grounds.

In total, 159 hunting grounds have been surveyed.

3.1. Physical-geographical framework of the areas studied.

3.1.1 Eastern Carpathians

3.1.1.1 Northern group.

3.1.1.1.1 High crystalline zone.

Structurally and petrographically, crystalline shales of Proterozoic and Paleozoic age predominate, which underwent complex metamorphic processes during the orogenesis period, with the emplacement of sedimentary layers of Paleogene age over the crystalline.

3.1.1.1.2 Eastern area of the Bukovina obcines

Characteristic of this area is the asymmetrical wave appearance of the succession of parallel ridges with steep eastern slopes and gently sloping western slopes, due to the activity of the shale beds (Roșu, 1980). The relief is characterized by low ridges, the average altitude being 1400 - 1500 m in Obcina Mestecănișului, between 1200 - 1300 m in Obcina Feredeului and below 1100 m in Obcina Mare (Barbu, Ionesi, 1987).

3.1.1.2. Central group.

Characteristic of this group is the crystalline-Mesozoic, felsic and volcanic structure with increasingly broad extension of the felsic and development of the eruptive chain, with a N-S orientation, resulting in a longitudinal orientation of the valleys.

3.1.1.2.1. Upper Midzone

Structurally-tectonic characteristics of this area are the crystalline-Mesozoic and felsic formations. The mountain massifs of this area are the Giumalău Massif, the Rarău Massif, the Ceahlău Massif, the Middle Bistriţa Mountains, the Giurgeu Mountains and the Hăşmaş Mountains (Roșu, 1980), involving the last three massifs from which study material has been taken.

3.1.1.2.2. Eastern area of the Fels Mountains

It is characterized in terms of the tectonics of the outer rift, by the size and extent of the Tarcău sheet with certain complications and digitations concretized by covering a common autochthon, the Vrancea unit (Mutihac, Ionesi, 1974).

3.1.1.2.3. Volcanic mountain area

The penetration of the crystalline-Mesozoic spur of the Rodna Mountains to the west perpendicularly interrupts the crustal fault and allows the development of a mixed sedimentary-eruptive relief with the appearance south of Bistriţa Ardeleană of a volcanic mountain chain, 150 km long and 50 km wide, consisting of the Călimani Mountains, the Gurghiu Mountains and the Harghitei Mountains (Roșu, 1980).

3.1.2. Curvature Group

The systemic landscape structures of the Eastern Carpathians found in tectonics, altitude and longitudinal orientation in relation to air mass movements are also present in the Curvature Carpathians, the mountainous area of the southern extremity of the Eastern Carpathians, as a subsystemic level, being characterized by certain structures of their own, which give them a particular geographical personality.

3.1.2.1. Outer Curvature Area

The Outer Curvature area is made up of mountain massifs separated by deep valleys or depressions of small size, divided into subunits of the fifth order: the Vrancei Mountains, the Buzău Mountains, the Penteleu Mountains, the Podul Calului Mountains, the Ivăneț Ridge, the Ciucaș Mountains, the Gârbovei Mountains, the Bârsei Mountains and on the northern side of Vrancea and Buzău a series of mountain peaks with altitudes of 800-1200 m, considered as the low mountains of the inland range: the Brețcu Mountains and the Întorsurii Mountains (Roșu, 1980).

3.1.2.2. Inner Curvature Area

The inner subunit of the curvature is less unitary with low altitudes (800-1200 m), having a domed relief and an increased petrographic variety (marly felsic, conglomerates, limestones, crystalline patches). It is formed by the Baraolt Mountains, the Bodoc Mountains as mountainous intrusions in the depression of Braşov and the Perșani Mountains, as a crossing area to the Transylvanian Plateau and a link with the Southern Carpathians (Roșu, 1980). The vegetation of these mountains is composed of 70% compact mixed and deciduous forests interspersed with meadows and enclaves.

3.1.3. Southern Carpathians

From these sub-units sampling was carried out in the Făgăraș - Păpușa, Cozia; Parâng - Cindrel, Şurean, Lotru; Godeanu-Retezat - Retezat, Godeanu and Vâlcan Massifs. A sample was also taken in the Poiana Ruscă Mountains, which are geologically and petrographically included in the western branch of the Meridionals, but are classified due to their low altitudes in the Western Carpathians (Roșu, 1980).

3.1.3.1. Făgăraș Massif

It presents unitary, massive, west-east oriented structures with landscape features between north and south facing slopes. Predominantly composed of crystalline schists interspersed with bands of amphibolite, limestone and dolomite, the main ridge is characterized by asymmetry, the northern slopes being steeper than the southern ones.

3.1.3.2. Parâng Massif

Bordered to the east by the Olt Valley and the Jiu Valley and the Streiului Valley to the west, the Parâng massif is the typical orographic node of the Romanian Carpathians (Roșu, 1980).

It is made up of a central high area, from which four mountain ranges diverge: to the east the Căpățâna Ridge, the Lotru Mountains and the Cindrel Ridge. To the north-west, between the Sebeș and Strei valleys, the Șurean Mountains are composed of crystalline schists with eruptive intrusions and Mesozoic limestones.

3.1.3.3. Godeanu-Retezat Massif

To the north, the Retezat Mountains, the highest step of the orographic node, with a mosaic petrographic distribution, the two parallel anticlines of eruptive nature generating two main ridges (Peleaga and Buta) which in turn form two other orographic complexes of which the Piule node (Retezatul Mic) makes the transition from Retezat to Godeanu.

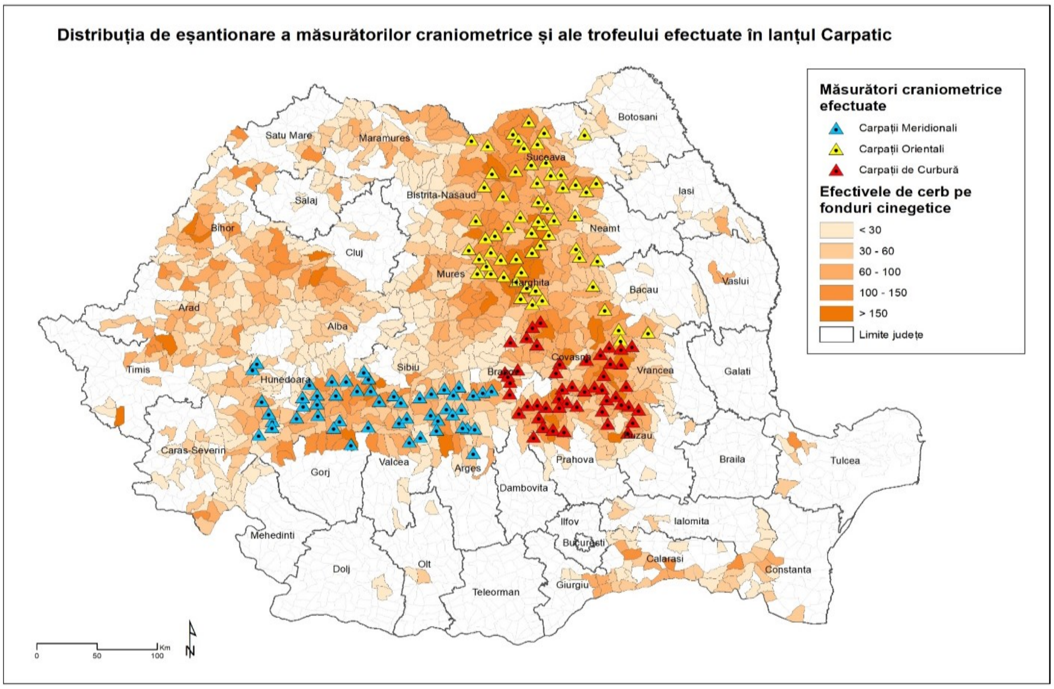

Fig. 7. Distribution of the sampled material

3.2. Material and method of work.

As mentioned in the previous paragraph, the biological material comes from three regions of the Carpathian chain, namely the Eastern Carpathians, the Curvature Carpathians and the Southern Carpathians. The establishment of these samples is based on the hypothesis of the existence of ecotypes in the Carpathian chain.

The 276 (274) skulls and trophies come from specimens harvested from the field during the 2017-2022 hunting season, the trophy collection of the Posada Hunting Museum, the trophy collection of the Faculty of Silviculture and Forest Enginerring, as well as from the personal collections of hunters in the areas mentioned.

3.2.1 Age determination

In the present study, premolar I of the upper jaw was extracted and sanded with 180-2000 grit sandpaper. The tooth thus processed was visually analysed under an electronic stereoscopic binocular with x100 objective magnification power.

Dark separation lines of secondary dental cement layers corresponding to the end of an annual growth are highlighted in the lateral areas of the pulp (Sîrbu, Simon, Spătaru, 2020). Age was obtained by counting these layers to which 3 years, the period of formation of the permanent dentition, were added (Fig. 8).

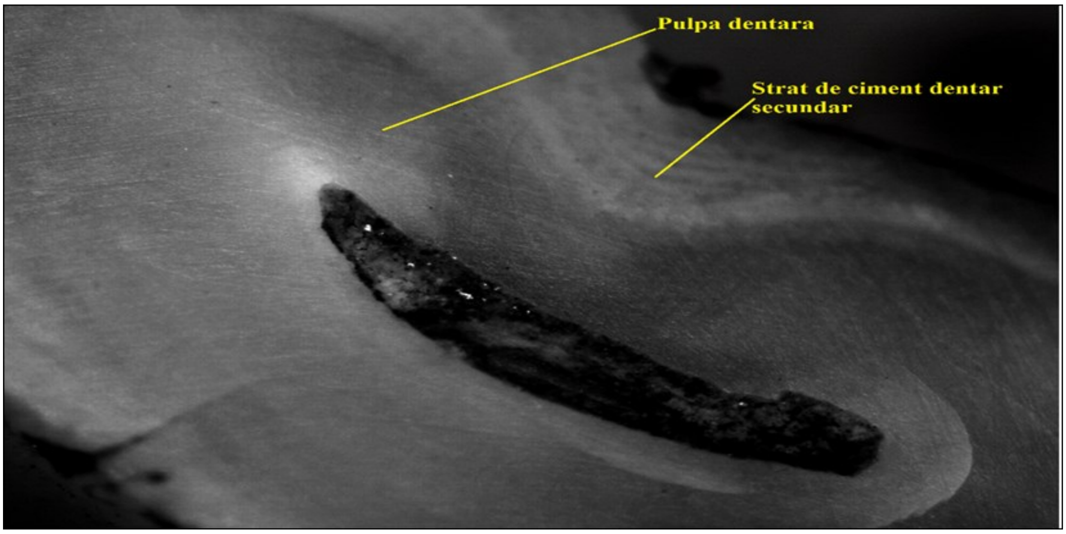

Fig. 10. Horizontal section through one of the roots of premolar I - 9-year-old deer specimen (photo Sîrbu, 2020).

Taking into account that, in general and only accidentally, specimens younger than 6 years old are extracted, males are chosen for harvest over 6 years old, the reasoning being valid also for trophies in collections (Sîrbu, Simon, Spătaru, 2020), and the small number of specimens in this category, in order to form a significant age class in terms of number of specimens, specimens under 7 years of age were excluded from the sample, resulting in two age classes: class I, aged 7 to 9 years, and class II, aged 10 and over.

The analysis resulted in the following samples in terms of geographical origin and age category (Table 1).

Table 1. Sampling of samples by geographical region and age.

Region	Total number of skulls	Age group I : 7-9 years	Age group II : ≥10 years
Eastern Carpathians	97	53	44
Curvature Carpathians	105	61	44
Southern Carpathians	72	51	21

3.2.2. Selection of variables for analysis

The 28 cranial variables were grouped and measured according to the model proposed by Duerst (1926) and Mystowska (1966) with modifications. These variables represent measurements made between the 15 bones that constitute the cranial architecture being grouped into four regions: dorsal face, ventral face, lateral face and occipital face (Sîrbu, Simon,
Spătaru, Codrean, 2022) (Fig. 11-15). Measurements were made with electronic calipers and values were expressed in millimetres with an accuracy of 0.1mm. Their acronyms are given in Tables 2, 3 and 4.

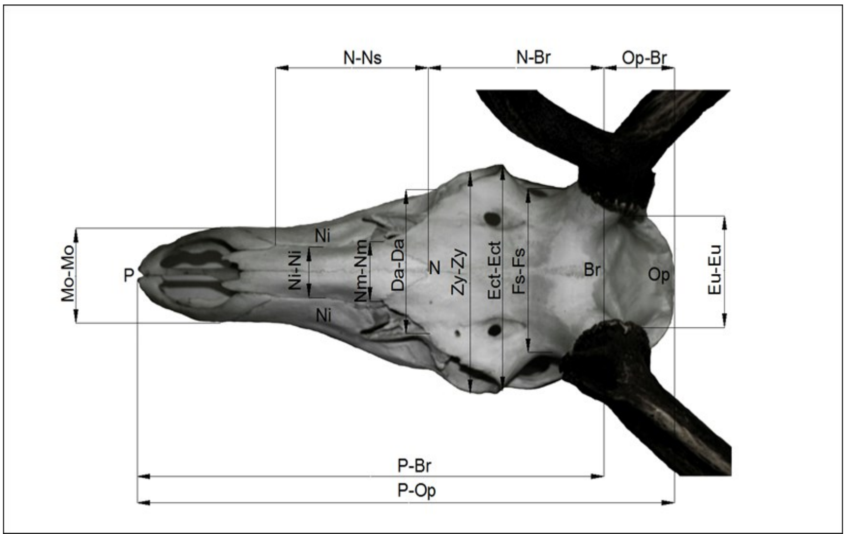

Fig. 11. Craniometric variables of the dorsal face (Sîrbu, Simon, Spătaru, 2020)

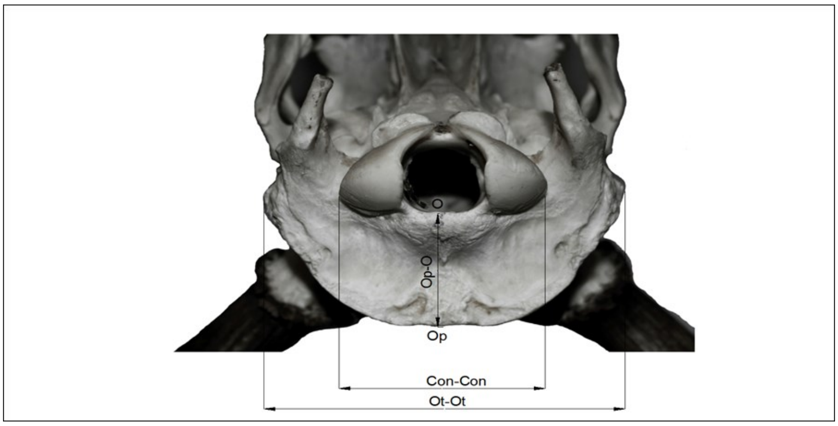

Fig. 12. Craniometric variables of the occipital face (Sîrbu, Simon, Spătaru, 2020)

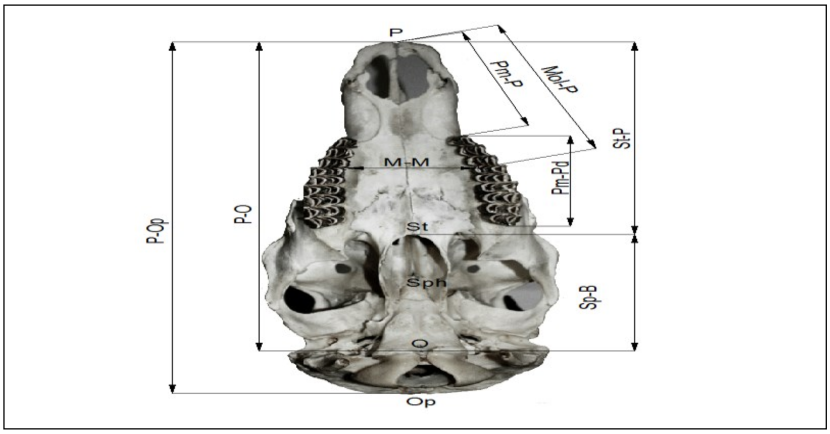

Fig. 13. Craniometric variables of the ventral face (Sîrbu, Simon, Spătaru, 2020)

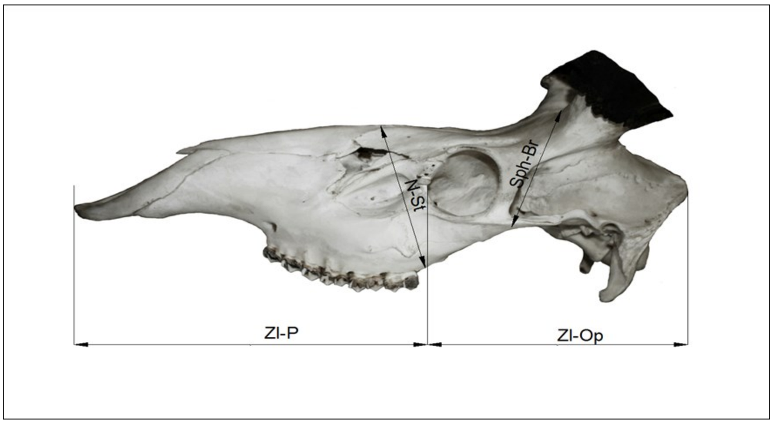

Fig. 14. Craniometric variables of lateral face, viscerocranial height (N-St) and neurocranial height (Sph-Br), (Sîrbu, Simon, Spătaru, 2020).

As for the trophy, 12 variables with structural and also horn assessment importance were selected (Fig. 15), their acronyms are given in Table 2. The measurements carried out followed the recent methodology using the CIC standards through "CIC Handbook for the Evaluation and Measurement of Hunting Trophies - 2019", (Spătaru, Sîrbu, Ionescu, 2021).

For the pairwise measurable variables (lengths, diameters) of the two rods, the values were expressed as arithmetic mean, including these, resulting in a single value (Sîrbu, Simon, Ionescu, Spătaru, Sîrbu, A. 2021).

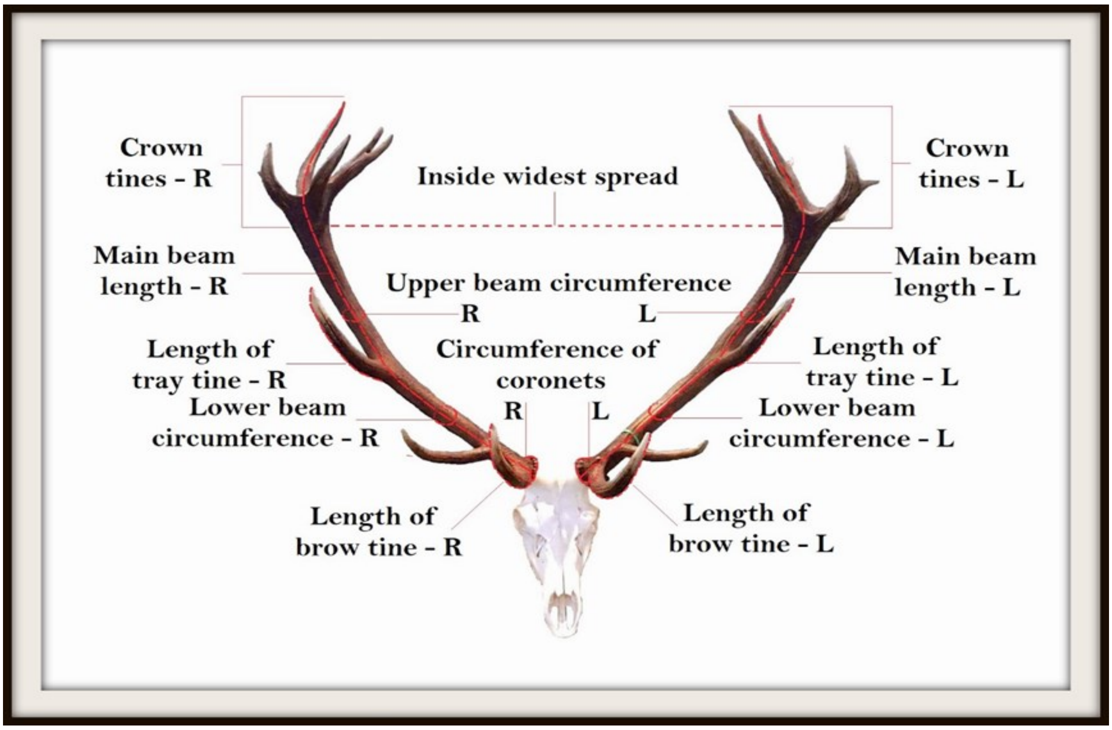

Fig. 15 Measurement scheme of trophy variables (Sîrbu, Simon, Ionescu, Spătaru, Sîrbu, A., 2021).

Table 2. Morphological elements (variables) of the dorsal face (Sîrbu, Simon, Spătaru, 2020).

No. crt.	**Acronym**	Explanation of cranial elements (variables)	**UM**
1	P -Op	Prostheon- opisthokranion - maximum skull length	mm
2	P-Br	Prostheon -Bregma - the length of the skull from the prostheon to the point of intersection of the frontal, parietal and occipital sutures	mm
3	Op-Br	Opisthokranion-Bregma - the length of the neurocranium , measured from the posterior end of the occipital bone to the point of intersection of the frontal, parietal and occipital sutures.	mm
4	N-Br	Nasion -Bregma - the length of the skull from the point where the nasal bones meet the frontal bones (P) and the point where the frontal, parietal and occipital sutures intersect (Br)	mm
5	N-Ns	Nasion-Ns - length measured from the point where the nasal bones meet the frontal bones (N) and the midpoint where the maxillary bones meet (Mo)	mm
6	Ni-Ni	Nasointermaxillary - the minimum distance between the nasal bones	mm
7	Mo-Mo	Maxillary - Maxillary - the width of the maxillary bones, measured at the level of the canines	mm
8	Nm-Nm	Naso maxillary-Nasomaxillary - maximum width of nasal bones	mm
9	Fs-Fs	Frontostenion - minimum width of the skull, measured at the base of the frontal cylinders	mm
10	I-I	Euryon-Euryon - maximum width of the neurocranium	mm
11	Zy-Zy	Zygion-Zygion - the width of the skull at orbital level, measured at the bottom of the orbital arch	mm
12	Ect-Ect	Ectoorbital-ectoorbital - the width of the skull, measured behind the orbital arch	mm
13	Da-Da	Dacryon- Dacryon - minimum width of frontal bones, measured at the edge of the eye sockets	mm

Table 3. Morphological elements (variables) of the lateral face, height of the viscerocranium (N-St) and neurocranium (Sph-Br) (Sîrbu, Simon, Spătaru, 2020).

No. crt.	**Acronym**	Explanation of cranial (variable) elements	**UM**
1	Zl-P	Zygolacrimale -Prostheon - length of viscerocranium	mm
2	Zl-Op	Zygolacrimale -Opistohokranion - neurocranial length	mm
3	N-St	Staphilyon -Nasion - height of the viscerocranium	mm
4	Sph-Br	Sphenobasion-Bregma - neurocranial height	mm

Table 4. Morphological elements (variables) of the ventral face (Sîrbu, Simon, Spătaru, 2020).

No. crt.	**Acronym**	Explanation of cranial elements (variables)	**UM**
1	P - B	Prostheon - Basion - skull base length	mm
2	P - O	Prostheon - opistion - length of skull from posterior plane of occipital condyles to prostion	mm
3	St - B	Staphilyon - Basion - the length of the base of the skull from the back of the hard palate to the anterior edge of the foramen magnum	mm
4	St - P	Staphilyon - Prostheon - dental palate length	mm
5	Mol - P	Molar - Prostheon - distance from prostheon to first molar	mm
6	Pm - P	Premolar - Prostheon - distance from prostheon to first premolar	mm
7	Pm- Pd	Premolar - Postdental - length of upper jaw teeth (P1-M3)	mm
8	M - M	Molars - Molar - width of cranial face at molar level I	mm

Table. 5. Morphological elements (variables) of the occipital face (Sîrbu, Simon, Spătaru, 2020).

No. crt.	**Acronym**	**Explanation of cranial (variable) elements**	**UM**
1	Ot - Ot	Otion-Otion - occipital bone width	mm
2	Con-Con	the measured width of the outer edges of the occipital condyles	mm
3	Op - O	Opistokranion-Opistion - maximum height of occipital face	mm

Table. 6. Trophy variables. (Sîrbu, Simon, Ionescu, Spătaru, Sîrbu, A., 2021).

Crt. no.	**Acronym**	**Explanation of the elements (variables) of the trophy**	**UM**
1	LP	Length of poles	cm
2	LRO	Length of eye radius	cm
3	LRM	Middle branch length	cm
4	RC	Circumference of rosettes	cm
5	CP1	Circumference of poles between RO and RM (minimum value)	cm
6	CP2	Circumference of poles between RO and crown (minimum value)	cm
7	DCF	Front cylinder diameter	mm
8	NRC	Number of branches in the crown	-
9	NRT	Total number of branches	-
10	Dmax	Maximum internal opening of the horns	cm
11	Dmin	Minimum internal opening of horns	cm
12	GR	Weight of horns and skull	kg

3.2.3. Elements of statistical processing and analysis

The recording and processing of the primary data was done using the XL2016 package. The Statistix Statsoft 12.1 package and XLSTAT Software were used for statistical analysis.

As a primary investigation technique, indices of experimental distributions expressed by mean values (arithmetic mean, weighted arithmetic mean), indices of dispersion expressed by variance, standard deviation, standard error of the means, coefficient of variation were used, the examination of significance being carried out using the theoretical distributions Student, Fisher, χ^2 (hi square), (Giurgiu, 1972).

Dispersion analysis was used to highlight differences between the samples analysed, and the statistical relationships established were investigated using correlation analysis and expressed by means of correlation coefficients and simple and multiple regression equations.

The interaction of ecological factors (biotic and abiotic) on the population often results in simultaneous causal relationships with pronounced feedback and expressed synergistically. (McGarigal et. al., 2000). These issues have been investigated using multivariate analysis techniques, Discriminant Analysis and Canonical Correlation Analysis as an extension of multiple regression).

Chapter 4. Research results and discussion

4.1. Research results for objective 1. Morpho-anatomical study of biological material for sampling and stratification of samples from the three regions studied, variation of cranial indices.

Biological material consisting of skulls and trophies was analysed for age using the method described in Chapter 3. 28 variables were selected from the morpho-anatomical analysis of the skull bones, 11 variables were selected for the trophy.

Taking age as a stratification factor, two groups resulted, namely group I aged 7-9 years and group II aged 10 years and over.

To this end, 11 cranial indices were calculated and analysed, by region and age group, following the model proposed by Mystowska (1966), and refer to the ratio of cranial bones defining the shape and size of the skull. To avoid negative values one of the variables was multiplied by the value 100. Their explanation is shown in Table 7.

Table 7. Explanation of cranial indices

Crt. no.	Acronym	Explanation of the index
1	Zy-Zy x 100/P-Op	The ratio of the maximum width of the skull to the total length of the skull.
2	Zy-Zy x 100/P-Br	The ratio of the maximum width of the skull to the point of intersection of the frontal, parietal and occipital bones.
3	St-N x 100/P-Op	The ratio of the height of the viscerocranium to the total length of the skull.
4	St-P x 100/P-Op	The ratio of the length of the viscerocranium to the total length of the skull.
5	Mo-Mo x 100/Pm-P	The ratio of the rostral width to the maximum anterior point of the skull in the midline on the alveolar process of the maxilla.
6	Br-N x 100/Ect-Ect	The ratio of the length of the frontal bone to the width of the skull measured behind the orbital arch.
7	Op-O x 100/Con	The ratio of the maximum height of the occipital plane to the width of the occipital condyles.
8	Eu-Eu x 100/St-B	The ratio of the width of the neurocranium to the length of the skull base.
9	M-M x 100/St-P	Ratio of viscerocranial width (facial tuberosity) to viscerocranial length.
10	N-Ns x 100/M-M	The ratio of the length of the nasal bone to the width of the viscerocranium (facial tuberosity)
11	Mo-Mo x 100/Pm-Pd	The ratio of the rostral width to the length of the row of teeth in the upper jaw.

Table 8. Cranial indices analysed

Group	Zy-Zy/P-Op	Zy-Zy/P-Br	St-N/P-Op	St-P/P-Op	Mo-Mo/Pm-P	Br-N/Ect-Ect	Op-O/Con	Eu-Eu/St-B	M-M/St-P	N-Ns/M-M	Mo-Mo/Pm-Pd
I-CO	39,62	47,69	22,25	57,31	50,29	82,92	81,99	72,56	44,06	104,03	65,55
II-CO	39,63	46,78	22,64	58,44	50,37	80,84	81,13	72,13	44,45	103,79	68,36
TOT CO	39,64	47,28	22,25	57,83	50,33	83,41	81,60	72,35	44,23	103,95	66,75
I CC	39,19	46,12	22,28	55,34	51,09	79,90	80,28	70,69	45,63	101,52	65,14
II CC	39,48	46,99	22,68	57,13	51,36	80,36	80,49	69,77	44,21	104,25	70,61
TOTAL CC	39,63	46,49	22,70	56,67	51,19	81,87	80,77	70,34	46,68	102,52	67,41
I-CM	39,22	45,87	20,57	57,30	51,33	83,42	82,18	70,02	44,67	105,04	66,29
II-CM	39,59	46,40	22,96	58,57	51,37	81,79	82,78	70,89	45,01	104,66	69,91
TotalCM	39,16	46,02	22,27	57,73	51,34	79,47	82,34	72,47	46,67	105,17	67,49

Note: CO - Eastern Carpathians, CC - Curvature Carpathians, CM - Southern Carpathians

The Zy-Zy/P-Op and Zy-Zy/P-Br indices illustrate the shape and size of the skull at the different measurement points as a ratio of its length to its width. It can be seen that the highest values are obtained by the Eastern Carpathians sample followed by the Curvature Carpathians and the Southern Carpathians. Also the highest values of this ratio are obtained by age group II for all three samples.

The St-N/P-Op index illustrates the height of the viscerocranium in relation to the total length of the skull, and the highest values are obtained by the Curvature Carpathians sample followed by the Southern Carpathians and the Eastern Carpathians, the highest values of this ratio are obtained by age group II for all three samples.

The St-P/P-Op index expresses the proportion of viscerocranial length to total skull length, the highest values are obtained by the Eastern Carpathians sample followed by the Southern Carpathians and the Curvature Carpathians. Also the highest values of this ratio are obtained by age group II for all three samples.

The highest values of the Mo-Mo/Pm-P index as a ratio of viscerocranial width to the maximum anterior point of the skull are also higher for group II in order: Southern Carpathians, Eastern Carpathians and Curvature Carpathians.

The Br-N/Ect-Ect index defining the ratio between the length and width of the frontal bones is higher for the Eastern Carpathians followed by the Curvature Carpathians and the Southern Carpathians. In terms of groups, a decrease in values is observed for all the three samples with increasing age, which was also observed in the deer samples studied in Poland (Mystowska, 1966).

The Op-O/Con-Con index has the highest values for the Southern Carpathians followed by the Eastern Carpathians and the Curvature Carpathians.

The ratio between the maximum width of the neurocranium and its length (Eu-Eu/St-B) has the highest values for the Southern Carpathians followed by the Eastern Carpathians and the Curvature Carpathians, by group, the highest values are obtained by the Eastern Carpathians sample.

The M-M/St-P index defining the ratio of the maximum width of the viscerocranium to the length of the dental palate has the highest values for the Southern Carpathians, followed by the Eastern Carpathians and the Curvature Carpathians.

For the I group, the order is the Curvature Carpathians, the Southern Carpathians and the Eastern Carpathians, and for group II the Southern Carpathians, the Eastern Carpathians and the Curvature Carpathians, the N-Ns/M-M index expressing the proportion between the length of the nasal bone and the facial tuberosity has the highest values for the Southern Carpathians sample followed by the Eastern Carpathians and

Curvature Carpathians, by group, the highest values are obtained by the Southern Carpathians sample.

The Mo-Mo/Pm-Pd index illustrates the rostral width in relation to the row of teeth of the maxilla, the highest values being obtained by the Southern Carpathians sample followed by the Curvature Carpathians and the Eastern Carpathians .For group I the order is, Southern Carpathians, Eastern Carpathians, respectively Curvature Carpathians and for group II Curvature Carpathians, Southern Carpathians and Eastern Carpathians.

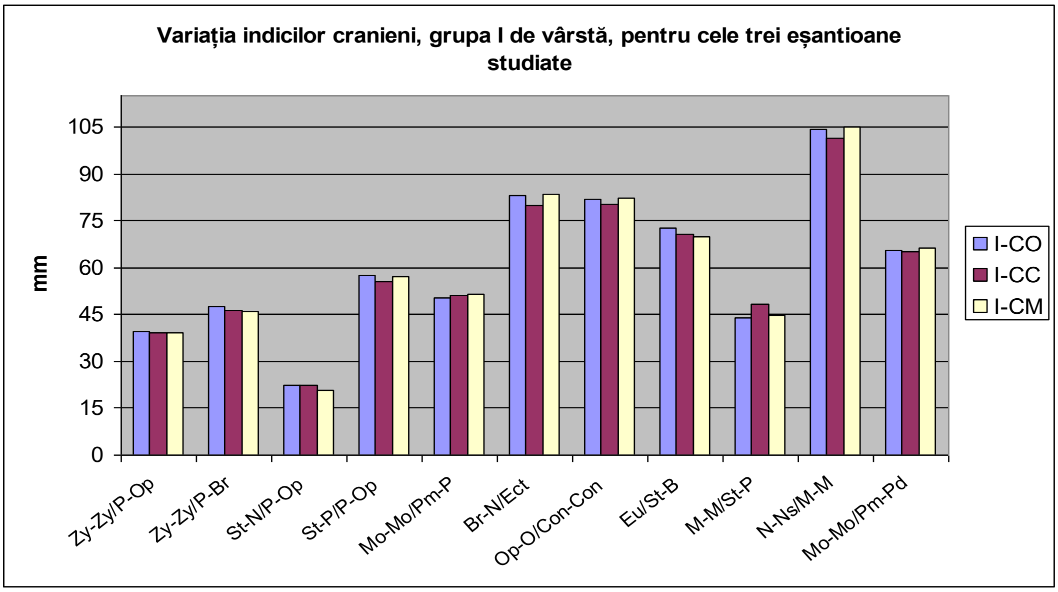

Fig. 16. Variation of cranial indices for age group I

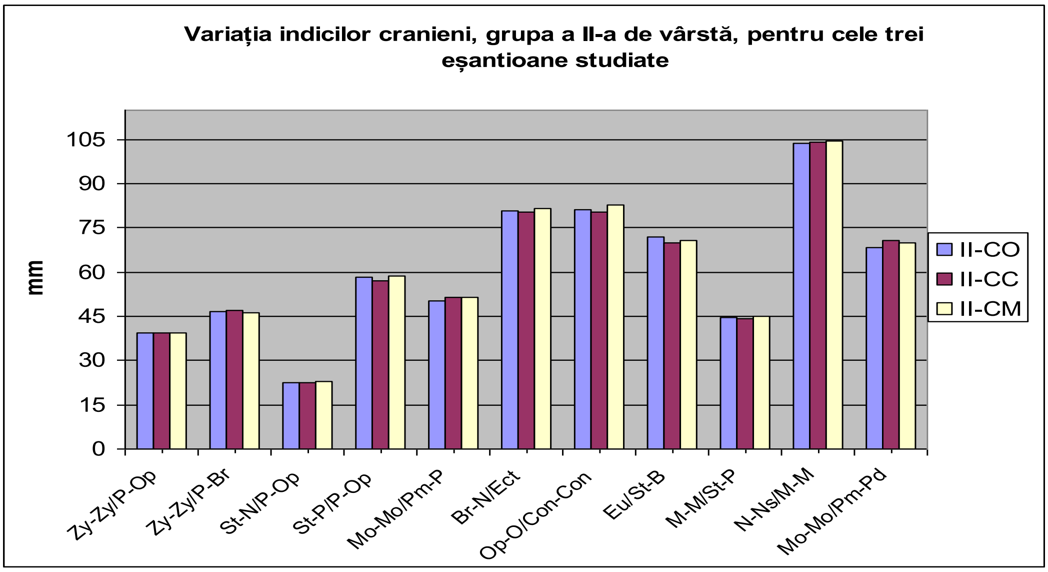

Fig.17.Variation of cranial indices for age group II

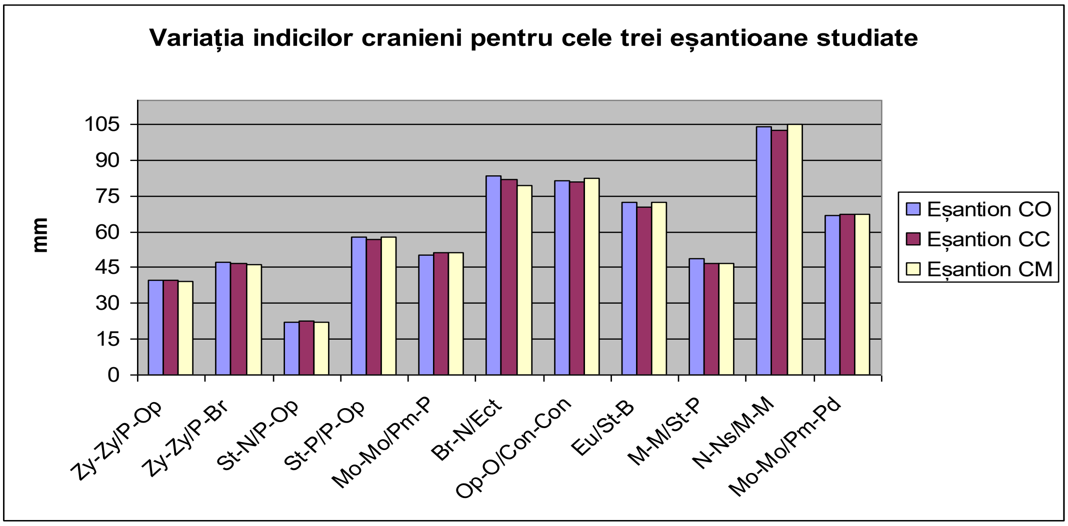

Fig.18. Variation of cranial indices for the three samples studied

Analysing the significance of the differences between the mean cranial indices, the following conclusions can be drawn: For the means of the Zy-Zy/P-Op index, there are no significant differences between the samples and the two age groups.

The averages of the Zy-Zy/P-Br index show a significant difference between the Eastern and Southern Carpathians in age group I. The means of the St-N/P-Op index do not show significant differences between samples and groups.

The means of the St-P/P-Op index show two distinctly significant differences for the 2nd age group, the first between the Eastern Carpathians and the Curvature Carpathians and the second between the Curvature Carpathians and the Southern Carpathians. The averages of the Mo-Mo/Pm-P index do not show significant differences between samples and groups.

The means of the Br-N/Ect-Ect index show only one significant difference, manifested in the 2nd age group, between the Eastern Carpathians and the Curvature Carpathians.

The means of the Op-O/Con-Con index do not show significant differences between samples and groups.

At the neurocranial level, the means of the Eu-Eu/St-B index show a distinctly significant difference between the Eastern Carpathians and the Curvature Carpathians samples, respectively a significant difference between the Eastern Carpathians and the Southern Carpathians samples.

At the viscerocranial level, the means of the M-M/St-P and N-Ns/M-M indices show no significant differences between samples and groups. The means of the Mo-Mo/Pm-Pd index show only one significant difference, at the second age group level, between the Eastern Carpathians and the Curved Carpathians.

4.2. Research results for objective 2. Multicriterial descriptive study of cranial and trophy elements from the three samples.

Multicriteria descriptive study of cranial and trophy elements refers to mean values (arithmetic mean, standard error of means) and dispersion indices (standard deviation and coefficient of variation), Student's and Fisher's theoretical distributions were used to examine significance.

4.2.1. Normality testing of dorsal face samples

As a first step in this analysis, the three samples were subjected to the normality test. The Shapiro-Wilk normality test analysis revealed that all cranial dorsal face elements in the three samples were normally distributed.

4.2.2. Analysis of statistical indices of the dorsal face. Analysis of variance.

The expression of variance by means of standard deviation and arithmetic mean in percentage form by means of the coefficient of variation was used to compare the distributions of backface elements in the three samples.

Thus, the coefficient of variation shows values of less than 10% for all age groups analysed and samples, which demonstrates low variability and therefore homogeneity of the samples extracted from the population. The exception is the Ni-Ni element characterising the minimum width of the nasal bones, for which the coefficient of variation values are around 10-13%.

A detailed comparative analysis of the coefficient of variation values revealed the following:

The P-Op, P-Br and Op-Br elements, which characterize the total skull length and contact regions measured between the neurocranium and viscerocranium show low variability for age group II compared to group I for all samples. At the sample level, the highest variability is shown by the Curvature Carpathians sample, with values of 7.76%.

The N-Br element, which defines the length of the frontal bone, shows the largest variations for age group II and, at the sample level, the Curvature Carpathians.

The length of the nasal bone defined by the distance N- Ns shows marked variations for the 2nd age group with the highest value for the Southern Carpathians and, at sample level, the Curvature Carpathians.

Rostral width, Mo-Mo shows larger variations for age group I, with the Curvature Carpathians at the top of the sample.

The maximum width of the nasal bones Nm-Nm, has the highest values for age group II, at the sample level the Southern Carpathians occupies the first place with the value of 10.08%.

The minimum skull width Fs-Fs, shows the largest variations for age group II, at sample level the Southern Carpathians come first.

The maximum width of the neurocranium, Eu-Eu shows the largest variations for age group II at the sample level, the Southern Carpathians are in the first place.

The maximum skull width expressed by the Zy-Zy element has the highest coefficient of variation values for age group II, at the sample level the Curvature Carpathians rank first.

The width of the skull behind the orbital arch, Ect-Ect, shows higher values for age group II, at the sample level, the Curvature Carpathians occupies the first place.

The width of the frontal bones, Da-Da, has higher values for age group I at the sample level of the new Curvature Carpathians takes the first place with the value of 6.45%.

The height of the viscerocranium expressed by the St-N element shows higher values of the coefficient of variation for age group II, with the Curvature Carpathians sample being in first position.

Neurocranial height, Sph- Br achieves higher values for age group II, and at sample level the Southern Carpathians occupies the first position.

For the first age group the Op-Br and Ect-Ect elements achieve very significant differences between the three samples, and the P-Op and Ni-Ni elements distinct significant differences. Significant differences are also found for the Zy-Zy and St-N elements. The other elements are not significant.

For the second age group, the P-Br item makes distinctly significant differences and the Ect-Ect item makes very significant differences. The other elements are not significant. The analysis of variance for total samples revealed significance between cranial elements as follows:

-The Op-Br and Ect-Ect items achieve very significant differences between the three samples. Differences between these structural elements defining the length neurocranium, i.e. the width of the frontal bones behind the orbital arch suggests significant changes in skull shape at the dorsal face.

-The elements P-Op, Zy-Zy and St-N achieve distinctly significant differences between the three samples. These elements define the maximum length and width of the skull, respectively the maximum height of the viscerocranium suggesting also significant changes in cranial dimensions.

-The P-Br, Ni-Ni, Da-Da and Eu-Eu elements defining the length of the viscerocranium, the minimum width of the nasal bones, the minimum width of the frontal bones and the width of the neurocranium with architectural role of the neurocranium and viscerocranium also make significant differences. Four elements do not make significant differences.

Table 10. Mean values and dispersion indices for backface elements by age group

Var.	Eastern Carpathians								Curvature Carpathians								Southern Carpathians							
	Group I				Group II				Group I				Group II				Group I				Group II			
	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.
P-Op	466,4	15,32	3,28	2,14	469,5	14,45	3,08	2,20	475,7	18,27	3,84	2,32	475,7	16,30	3,43	2,58	468,7	16,46	3,51	2,45	468,6	15,19	3,24	3,58
P-Br	395,9	14,33	3,62	2,01	400,7	14,76	3,68	2,25	399,8	16,50	4,13	2,15	410,4	14,54	3,54	2,22	400,9	16,38	4,09	2,44	400,1	16,53	4,13	3,90
Op-Br	97,9	7,61	7,77	1,05	99,1	6,75	6,81	1,01	103,1	7,69	7,46	0,98	102,0	8,41	8,25	1,30	98,3	7,26	7,38	1,02	100,2	6,65	6,64	1,45
N-Br	142,6	7,82	5,48	1,08	141,8	8,93	6,30	1,33	145,6	11,78	8,09	1,50	144,8	13,02	8,99	1,99	143,0	12,01	8,39	1,68	139,8	11,61	8,31	2,53
N-Ns	124,3	11,00	8,85	1,53	126,3	9,66	7,65	1,47	126,0	11,04	8,77	1,40	126,9	10,98	8,65	1,69	126,7	10,69	8,43	1,53	128,2	12,40	9,68	2,77
Ni-Ni	33,8	3,76	11,12	0,52	35,7	4,15	11,63	0,63	36,3	3,81	10,49	0,48	36,4	3,64	10,00	0,56	34,9	4,68	13,40	0,67	37,0	4,48	12,11	0,98
Mo-Mo	77,2	3,82	4,94	0,53	78,2	4,75	6,07	0,72	78,6	4,79	6,09	0,61	78,3	4,35	5,56	0,67	77,9	4,65	5,96	0,67	80,6	3,84	4,76	0,91
Nm-Nm	55,3	4,32	7,81	0,60	56,8	4,63	8,16	0,70	55,7	5,48	9,84	0,70	56,7	5,69	10,04	0,88	56,8	5,60	9,86	0,78	55,7	5,98	10,73	1,30
Fs-Fs	129,3	4,21	3,26	0,58	129,5	3,57	2,76	0,53	131,2	5,76	4,39	0,73	130,3	7,19	5,51	1,10	130,4	6,82	5,23	0,96	130,9	7,18	5,49	1,57
I-I	108,5	4,43	4,08	0,61	107,8	4,16	3,86	0,62	110,2	4,28	3,88	0,54	109,6	3,88	3,54	0,59	108,7	4,71	4,34	0,67	108,8	5,57	5,12	1,21
Zy-Zy	185,6	6,53	3,52	0,91	185,9	5,11	2,75	0,76	186,8	7,43	3,98	0,94	188,1	7,54	4,01	1,15	183,4	6,40	3,49	0,91	184,4	7,26	3,94	1,58
Ect-Ect	171,2	7,91	4,62	1,10	170,7	9,24	5,41	1,38	177,6	9,66	5,44	1,23	178,7	8,64	4,84	1,32	170,5	8,12	4,77	1,14	170,1	8,85	5,20	1,93
Da-Da	133,4	6,59	4,94	0,91	133,2	7,17	5,38	1,07	133,6	9,31	6,97	1,19	134,0	7,67	5,72	1,17	130,7	6,75	5,17	0,95	131,1	5,88	4,49	1,28
St-N	105,3	4,58	4,35	0,64	106,0	5,77	5,44	0,87	107,9	6,15	5,70	0,79	108,4	6,22	5,74	0,98	105,4	5,58	5,30	0,83	107,1	5,91	5,52	1,29
Sph-Br	108,8	4,97	4,57	0,70	109,9	5,52	5,02	0,86	110,0	5,52	5,02	0,71	110,1	4,09	3,72	0,66	107,8	5,16	4,78	0,77	111,6	5,63	5,05	1,23

Note: Var-elements (variables), m- mean, sd- standard deviation , cv%- coefficient of variation, er.std.- standard error of means

Table 11. Mean values and dispersion indices for backface elements per total sample

Var.	Eastern Carpathians				Curvature Carpathians				Southern Carpathians			
	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.
P-Op	467,80	14,926	3,191	1,539	475,73	17,445	3,667	1,727	468,66	15,985	3,411	2,014
P-Br	398,10	14,648	3,679	1,511	404,28	16,497	4,081	1,633	400,68	16,296	4,067	2,053
Op-Br	98,48	7,208	7,319	0,732	102,63	7,966	7,761	0,781	98,87	7,090	7,171	0,836
N-Br	142,24	8,319	5,849	0,845	145,29	12,251	8,432	1,196	142,09	11,905	8,379	1,403
N-Ns	125,21	10,411	8,314	1,068	126,36	10,974	8,684	1,076	127,14	11,137	8,760	1,341
Ni-Ni	34,66	4,026	11,616	0,413	36,36	3,726	10,247	0,365	35,56	4,686	13,177	0,560
Mo-Mo	77,70	4,271	5,497	0,438	78,49	4,599	5,860	0,451	78,65	4,580	5,823	0,564
Nm-Nm	55,95	4,502	8,046	0,459	56,08	5,557	9,910	0,545	56,46	5,691	10,080	0,671
Fs-Fs	129,40	3,908	3,020	0,397	130,84	6,364	4,864	0,621	130,58	6,882	5,270	0,811
I-I	108,20	4,302	3,976	0,437	109,91	4,108	3,738	0,401	108,71	4,943	4,547	0,591
Zy-Zy	185,78	5,887	3,169	0,598	187,32	7,465	3,985	0,728	183,68	6,633	3,611	0,793
Ect-Ect	170,99	8,515	4,980	0,865	178,07	9,226	5,181	0,900	170,36	8,282	4,862	0,976
Da-Da	133,29	6,831	5,125	0,694	133,74	8,632	6,455	0,846	130,79	6,473	4,949	0,763
St-N	105,63	5,141	4,867	0,525	108,11	6,151	5,690	0,615	105,94	5,701	5,382	0,702
Sph-Br	109,26	5,218	4,776	0,544	110,02	4,987	4,533	0,501	109,03	5,558	5,097	0,684

Note: Var-elements (variables), m- mean, sd- standard deviation, cv%-coefficient of variation, er. std.-standard error of means.

Table 12. Analysis of variance of backbone elements for group I and II, Eastern Carpathians, Curvature Carpathians and Southern Carpathians.

Analysis of variance, α =0.05, α =0.01, α =0.001											
Group I						Group II					
Var.	SS	MS	F	p	df	Var.	SS	MS	F	p	df
P-Op	2695,83	1347,92	4,746	0,0100**	2	P-Op	1032,20	516,10	2,194	0,1170^{nes}	2
P-Br	690,42	345,21	1,385	0,2534^{nes}	2	P-Br	2478,55	1239,28	5,521	0,0053**	2
Op-Br	951,48	475,74	8,390	0,0003***	2	Op-Br	180,44	90,22	1,636	0,1997^{nes}	2
N-Br	301,59	150,79	1,300	0,2754^{nes}	2	N-Br	413,80	206,90	1,645	0,1979^{nes}	2
N-Ns	159,14	79,57	0,667	0,5147^{nes}	2	N-Ns	46,91	23,46	0,203	0,8166^{nes}	2
Ni-Ni	173,89	86,95	5,233	0,0063**	2	Ni-Ni	28,11	14,06	0,868	0,4227^{nes}	2
Mo-Mo	53,22	26,61	1,340	0,2649^{nes}	2	Mo-Mo	82,84	41,42	2,097	0,1281^{nes}	2
Nm-Nm	62,28	31,14	1,160	0,3161^{nes}	2	Nm-Nm	17,47	8,74	0,307	0,7367^{nes}	2
Fs-Fs	98,98	49,49	1,526	0,2205^{nes}	2	Fs-Fs	34,01	17,01	0,479	0,6206^{nes}	2
I-I	91,62	45,81	2,304	0,1032^{nes}	2	I-I	68,46	34,23	1,802	0,1700^{nes}	2
Zy-Zy	324,59	162,30	3,458	0,0339*	2	Zy-Zy	212,52	106,26	2,453	0,0909^{nes}	2
Ect-Ect	1804,6	902,34	11,998	0,0000***	2	Ect-Ect	1740,49	870,24	10,899	0,0000***	2
Da-Da	279,37	139,69	2,319	0,1016^{nes}	2	Da-Da	116,73	58,36	1,141	0,3234^{nes}	2
St-N	238,51	119,26	3,930	0,0216*	2	St-N	125,29	62,64	1,757	0,1778^{nes}	2
Sph-Br	119,77	59,89	2,178	0,1167^{nes}	2	Sph-Br	45,36	22,68	0,893	0,4127^{nes}	2

Note: Var - Variable, SS - sum of squares, MS - mean of squares, F - Fisher statistic, p - critical value, df - degree of freedom, * -significant, ** - distinctly significant, ***- highly significant, not-significant

Table 13. Analysis of variance of backbone elements for the Eastern Carpathians, Curvature Carpathians and Southern Carpathians samples.

Analysis of variance, α =0.05, α =0.01, α =0.001								
Variable	**SS**	**MS**	**df**	**SS err.**	**MS err.**	**df err.**	**F**	**p**
P-Op	3577,386	1788,693	2	67298,25	262,8838	256	6,8041	0,0013**
P-Br	1888,661	944,330	2	63906,09	249,6332	256	3,7829	0,0240*
Op-Br	1029,387	514,693	2	15092,92	55,8997	270	9,2074	0,0001***
N-Br	628,194	314,097	2	32315,96	119,2471	271	2,6340	0,0736^{nes}
N-Ns	156,177	78,089	2	31027,05	117,0832	265	0,6670	0,5141^{nes}
Ni-Ni	143,015	71,508	2	4468,38	16,7984	266	4,2568	0,0151*
Mo-Mo	44,944	22,472	2	5256,82	20,0642	262	1,1200	0,3278^{nes}
Nm-Nm	11,165	5,582	2	7406,09	27,5319	269	0,2028	0,8166^{nes}
Fs-Fs	114,224	57,112	2	9041,04	33,3618	271	1,7119	0,1825^{nes}
I-I	155,446	77,723	2	5218,14	19,3983	269	4,0067	0,0193*
Zy-Zy	555,650	277,825	2	12158,09	45,1973	269	6,1469	0,0025**
Ect-Ect	3517,698	1758,849	2	20682,51	76,3192	271	23,0459	0,0000***
Da-Da	405,223	202,611	2	15128,93	56,0331	270	3,6159	0,0282*
St-N	345,551	172,776	2	8369,28	32,3138	259	5,3468	0,0053**
Sph-Br	46,000	23,00	2	6922,50	27,2539	254	0,8439	0,4312^{nes}

Note: SS - sum of squares, MS - mean of squares, SS err - sum of residual squares, MS err - mean of residual squares, df err - residual degrees of freedom, F - Fisher statistic, p-critical value, * -significant, ** - distinctly significant, ***- highly significant, not-significant.

4.2.3 Testing of normality of ventral, lateral and occipital face samples.

The three samples were subjected to the Shaphiro-Wilk normality test. Analysis of the Shapiro-Wilk normality test revealed that all cranial elements of the ventral, lateral and occipital face in the three samples were normally distributed.

4.2.4. Analysis of statistical indices of ventral, lateral and occipital face. Analysis of variance.

A detailed comparative analysis of the coefficient of variation values revealed the following:

The elements P-B, St-B, Mol-P, Pm-Pd, M-M, Zl-P, Zl-Op, Ot-Ot, and Op-O have for age group I, Eastern Carpathians sample coefficient values ranging from 3.04-7.15% higher than in age group II with values between 2.4-5.52%. The elements P-O, St-P, Pm-P and Con-Con have for age group II values between 3.09-4.36% higher than in age group I with values between 3.00-4.19%.

The elements St-P, M-M, Zl-Op, and Ot-Ot have for the age group I, Curvature Carpathians sample coefficient of variation values between 4.36 -5.92% higher than those of age group II with values between 3.89-5.86%. The elements P-B, P-O, St-B, Mol-P, Pm-P, Pm-Pd, Con-Con and Op-O have for age group II values of the coefficient of variation between 3.15-5.86% higher than those of age group I with values of 3.07-4.92%.

The elements P-O, St-P, Mol-P, M-M, Zl-Op and Con-Con have for age group I, Southern Carpathians sample coefficient of variation values between 3.54-5.11% higher than age group II with values between 2.96-3.66. The elements P-B, St-B, Pm-P, Pm-Pd, Zl-P and Ot-Ot have for age group II coefficient of variation values of 4.41-7.43% higher than those of age group I with values of 3.54-7.41.

Regarding the samples in total (Table 15), the following observations can be made: for the elements P-B, P-O, St-B and Pm-P, the Southern Carpathians sample has the highest coefficient of variation values with values of 3.37-5.35%, followed by the Curvature Carpathians sample with values between 3.30-5.19% and the Eastern Carpathians with values of 3.03-4.69%. The values of St-B, Mol-P and Pm-Pd elements have coefficients of variation values of 4.53-5.21% for the Curvature Carpathians with values of 4.18-4.58%, followed by the Southern Carpathians with values of 4.18-4.58% and the Eastern Carpathians with 2.92-3.51.

The M-M element defining the width of the viscerocranium has higher values for the Curvature Carpathians, followed by the Eastern Carpathians and the Southern Carpathians. For the elements Zl-P, Zl-Op, Ot-Ot, Con-Con and Op-O the coefficient of variation values have the highest values (4.15-7.36%) for the Southern Carpathians, followed by the Curvature Carpathians (4.05-4.45%) for the first three elements and the Eastern Carpathians (3.61-4.39%). The elements Con-Con and Op-O have higher values for the Eastern Carpathians.

As an overall observation, it can be stated that the degree of variability of the ventral, lateral and occipital face elements is higher for the Southern Carpathians sample, followed by the Curvature Carpathians and the Eastern Carpathians, except for two ventral face elements (St-P, Mol-P), where the values are higher in favour of the Curvature Carpathians and two occipital face elements where the Eastern Carpathians values are higher than those of the Curved Carpathians.

The applied analysis of variance (Table 16) revealed the following:

For age group I the St-B elements, representing the length of the base of the neurocranium, i.e. Con-Con, the width of the occipital condyles make very significant differences. Mol-P and Pm-P elements as viscerocranium lengths achieve very significant differences. The other elements do not show significant differences.

For age group II the St-B element and Zl -Op as total neurocranial length achieve very significant differences.

The elements P-B and P-O as skull lengths, Zl-P as viscerocranial length and con-con as occipital condyle width make very significant differences.

The Ot-Ot element as width of the occipital bones also make very significant differences. The other elements do not show significant differences.

Presence of statistically strong significance of different elements in age group II where all bone growth processes and obliteration of all sutures between the component bones is completed, suggests that the cranial architecture is relatively stable, compared to age group I where these processes are not fully completed. Also, it can be suggested that a comparative craniometric analysis could be performed on samples belonging to this age group.

The analysis of variance by total sample (Table 17) revealed the following:
The St-B, Zl-Op and con-con elements achieve very significant differences between the three samples. The Ot-Ot and P-B elements achieve distinctly significant differences respectively between the three samples.

Table 14. Mean values and dispersion indices for ventral lateral and occipital face elements by age group.

Var.	Eastern Carpathians								Curved Carpathians								Southern Carpathians							
	Group I				Group II				Group I				Group II				Group I				Group II			
	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.
P-B	422,7	12,83	3,04	1,81	424,5	10,18	2,40	1,63	423,6	14,68	3,46	1,94	435,1	16,16	3,71	2,56	421,7	15,47	3,67	2,31	429,4	19,20	4,47	4,80
P-O	449,4	13,46	3,00	1,90	451,4	13,94	3,09	2,18	451,9	13,86	3,07	1,84	462,8	14,60	3,15	2,31	451,6	15,98	3,54	2,36	452,0	13,36	2,96	3,34
St-B	150,3	7,70	5,13	1,09	149,9	6,23	4,16	0,97	154,5	6,78	4,39	0,90	158,8	8,58	5,40	1,36	149,4	7,63	5,11	1,11	152,8	7,93	5,19	1,82
St-P	271,5	7,37	2,72	1,03	273,7	8,54	3,12	1,32	268,9	11,73	4,36	1,55	277,0	11,70	4,23	1,81	271,6	11,87	4,37	1,77	275,0	10,07	3,66	2,37
Mol-P	205,2	6,28	3,06	0,88	204,9	6,18	3,02	0,95	201,3	6,94	3,45	0,90	206,3	9,32	4,52	1,44	204,5	8,35	4,08	1,22	206,7	6,98	3,38	1,64
Pm-P	154,4	4,98	3,23	0,70	155,4	5,96	3,84	0,92	150,5	6,69	4,44	0,87	157,7	7,78	4,93	1,20	152,0	7,64	5,03	1,11	157,2	8,67	5,51	2,04
Pm-Pd	117,9	5,16	4,38	0,72	114,4	4,96	4,33	0,76	118,4	5,45	4,60	0,70	114,4	6,26	5,47	0,97	118,5	4,96	4,19	0,70	114,4	5,31	4,64	1,16
M-M	119,9	6,35	5,30	0,88	121,2	5,33	4,40	0,80	122,4	7,25	5,92	0,94	122,6	7,18	5,86	1,11	121,3	6,13	5,05	0,88	122,0	4,55	3,73	0,99
Zl-P	273,7	10,35	3,78	1,43	276,9	9,26	3,34	1,41	275,4	10,70	3,88	1,38	283,8	10,37	3,65	1,58	276,5	11,65	4,21	1,70	277,1	12,22	4,41	2,88
Zl-Op	217,9	8,10	3,72	1,13	219,6	7,06	3,22	1,06	220,5	9,01	4,08	1,14	224,7	9,05	4,03	1,40	217,6	9,50	4,36	1,33	217,0	7,95	3,66	1,74
Ot-Ot	148,0	7,22	4,88	1,00	150,0	5,50	3,67	0,83	148,4	6,44	4,34	0,84	153,4	5,97	3,89	0,92	146,6	6,88	4,70	0,96	148,0	8,49	5,73	1,85
Con-Con	78,1	3,27	4,19	0,46	78,7	3,43	4,36	0,54	80,1	2,74	3,42	0,36	80,9	3,32	4,10	0,52	77,3	3,81	4,93	0,54	78,0	3,17	4,07	0,73
Op-O	63,7	4,55	7,15	0,64	63,7	3,51	5,52	0,54	64,1	3,15	4,92	0,41	65,3	3,83	5,86	0,61	63,5	4,70	7,41	0,66	63,7	4,73	7,43	1,09

Note: Var - items (variables), m - mean, sd - standard deviation, cv% - coefficient of variation, er.std - standard error of means

Table 15. Mean values and dispersion indices for ventral, lateral and occipital face elements per total sample.

Var.	Eastern Carpathians				Curved Carpathians				Southern Carpathians			
	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.
P-B	423,5	11,71	2,77	1,24	428,3	16,24	3,79	1,65	423,8	16,71	3,94	2,14
P-O	450,3	13,64	3,03	1,43	456,4	15,07	3,30	1,53	451,7	15,24	3,37	1,94
St-B	150,1	7,04	4,69	0,74	156,2	7,56	4,84	0,77	150,4	7,81	5,19	0,96
St-P	272,5	7,96	2,92	0,83	272,3	12,33	4,53	1,24	272,6	11,41	4,18	1,44
Mol-P	205,1	6,21	3,03	0,64	203,4	8,35	4,11	0,83	205,1	8,00	3,90	0,99
Pm-P	154,8	5,44	3,51	0,56	153,5	7,97	5,19	0,79	153,4	8,21	5,35	1,02
Pm-Pd	116,3	5,35	4,60	0,55	116,7	6,09	5,21	0,60	117,3	5,37	4,58	0,63
M-M	120,5	5,92	4,91	0,60	122,4	7,19	5,87	0,71	121,5	5,67	4,67	0,68
Zl-P	275,1	9,95	3,61	1,02	278,9	11,30	4,05	1,11	276,7	11,72	4,23	1,45
Zl-Op	218,7	7,64	3,49	0,78	222,2	9,21	4,15	0,90	217,4	9,02	4,15	1,06
Ot-Ot	148,9	6,54	4,39	0,67	150,5	6,70	4,45	0,67	147,0	7,36	5,01	0,87
Con-Con	78,4	3,34	4,27	0,35	80,4	3,00	3,73	0,30	77,5	3,64	4,69	0,44
Op-O	63,7	4,09	6,42	0,43	64,6	3,48	5,39	0,35	63,5	4,68	7,36	0,56

Note: Var-elements (variables), m - mean, sd - standard deviation, cv% - coefficient of variation, er.std - standard error of means.

Table 16. Analysis of variance of ventral, lateral and occipital face elements by age group for the Eastern Carpathians, Curvature Carpathians and Southern Carpathians samples.

Analysis of variance, α =0.05, α =0.01, α =0.001											
Group I						Group II					
Var.	SS	MS	F	p	df	Var.	SS	MS	F	p	df
P-B	88,57	44,29	0,215	0,8066^{nes}	2	P-B	2205,67	1102,83	5,163	0,0075**	2
P-O	191,89	95,95	0,462	0,6306^{nes}	2	P-O	2945,81	1472,90	7,379	0,0011**	2
St-B	788,69	394,35	7,294	0,0009***	2	St-B	1657,81	828,91	14,474	0,0000***	2
St-P	248,19	124,10	1,120	0,3291^{nes}	2	St-P	220,26	110,13	1,055	0,3520 ^{nes}	2
Mol-P	496,19	248,09	4,794	0,0096**	2	Mol-P	60,37	30,18	0,502	0.6069 nes	2
Pm-P	412,75	206,37	4,874	0,0089**	2	Pm-P	124,38	62,19	1,181	0,3112^{nes}	2
Pm-Pd	8,71	4,36	0,160	0,8519^{nes}	2	Pm-Pd	0,14	0,07	0,002	0,9977^{nes}	2
M-M	170,76	85,38	1,938	0,1474^{nes}	2	M-M	38,30	19,15	0,531	0,5896^{nes}	2
Zl-P	200,11	100,05	0,846	0,4312^{nes}	2	Zl-P	1180,29	590,14	5,595	0,0050**	2
Zl-Op	286,15	143,08	1,809	0,1671^{nes}	2	Zl-Op	989,78	494,89	7,609	0,0008***	2
Ot-Ot	101,65	50,83	1,087	0,3398^{nes}	2	Ot-Ot	476,84	238,42	5,901	0,0037**	2
Con-Con	233,12	116,56	10,847	0,0000***	2	Con-Con	147,21	73,61	6,601	0,0021**	2
Op-O	9,97	4,99	0,290	0,7487nes	2	Op-O	63,31	31,66	2,094	0,1287nes	2

Note: Var - Variable, SS - sum of squares, MS - mean of squares, F - Fisher statistic, p - critical value, df - degree of freedom, * -significant, ** - distinctly significant, ***- highly significant, non-significant.

Table 17. Analysis of variance of lateral ventral and occipital face elements for the Eastern Carpathians, Curvature Carpathians and Southern Carpathians samples.

Analysis of variance, α =0.05, α =0.01, α =0.001								
Variable	SS	MS	df	SS err.	MS err.	df err.	F	p
P-B	1324,915	662,458	2	54149,28	221,923	244	2,985	0,0524nes
P-O	1887,317	943,659	2	52726,39	213,467	247	4,421	0,0130*
St-B	2129,463	1064,732	2	13912,57	55,429	251	19,209	0,0000***
St-P	2,621	1,311	2	28777,44	114,196	252	0,011	0,9886^{nes}
Mol-P	185,428	92,714	2	14617,08	57,098	256	1,624	0,1992^{nes}
Pm-P	107,407	53,704	2	13377,05	52,254	256	1,028	0,3593^{nes}
Pm-Pd	38,358	19,179	2	8484,54	31,897	266	0,601	0,5489^{nes}
M-M	186,446	93,223	2	10761,14	40,608	265	2,296	0,1027^{nes}
Zl-P	719,452	359,726	2	31098,89	119,611	260	3,007	0,0511^{nes}
Zl-Op	1102,897	551,449	2	20015,30	74,684	268	7,384	0,0008***
Ot-Ot	523,455	261,728	2	12390,19	46,580	266	5,619	0,0041**
Con-Con	397,324	198,662	2	2790,02	10,899	256	18,228	0,0000***
Op-O	55,769	27,884	2	4184,24	16,345	256	1,706	0,1836^{nes}

Note: SS - sum of squares, MS - mean of squares, SS err .- sum of residual squares, MS err - mean of residual squares, df err. - residual degrees of freedom, F - Fisher statistic, p - critical value, * -significant, ** - distinctly significant, ***- highly significant.

4.2.5. Analysis of statistical indices for trophy elements. Analysis of variance.

This wide variation can be attributed to ecological and nutritional factors, with genetics also playing an important role. Analysis of the coefficients of variation between groups revealed the following:

The elements NRC, NRT and GR, i.e. number of branches in the crown, total number of branches and trophy weight, show the highest coefficient of variation values for age group I in all three samples (17.71%, 9.34%, 19.37%) compared to age group II (12.43%, 7.60%, 8.05%).The variation of the NRC element is maximum for the Curvature Carpathians, followed by the Eastern Carpathians and the Southern Carpathians. The variation of the NRT element is also maximum for the Curvature Carpathians followed by the Eastern Carpathians and the Southern Carpathians, as well for the GR element.

DCF, Dmax and LP, i.e. diameter of front cylinders, maximum pole opening and pole length have the highest variations for age group I compared to age group II, with the ranking again in favour of the Curved Carpathians.

For D min, the minimum pole opening variation is larger for age group II in order: Curvature Carpathians, Southern Carpathians and Eastern Carpathians.

The LRO element, eye radius length, shows larger variations for group I than for group II for the Eastern Carpathians and the Curvature Carpathians, with the element variations being more pronounced for group II in the case of the Southern Carpathians.

The LRM element, mid-radius length, shows larger variations for group II than group I for the Curvature Carpathians and Southern Carpathians, with smaller element variations for the Eastern Carpathians.

The CR element, rosette circumference, shows larger variations for group I than for group II for the Eastern Carpathians and the Curvature Carpathians, with the element variations being more pronounced for group II in the case of the Southern Carpathians.

Items CP1 and CP2, the pole circumferences measured between the eye radius and the mid - and crown radius, respectively, have larger variations for age group I than for age group II.

The variation at total sample level shows the following:

DCF, NRC, Dmax, Dmin, LP, NTR and GR have the highest values for the Curvature Carpathians, followed by the Eastern Carpathians and the Southern Carpathians.

For CP1 and CP2 and LRM elements, the variation is highest for the Curvature Carpathians followed by the Southern Carpathians and the Eastern Carpathians.

For the CR element the values of the coefficients of variation are higher for the Eastern Carpathians followed by the Curvature Carpathians and the Southern Carpathians.

The LRO element variation is highest for the Southern Carpathians followed by the Eastern Carpathians and the Curvature Carpathians.

A final conclusion on trophy elements suggests that age group I shows the greatest variation. This marked variation can be attributed to the fact that up to a certain age the growth process is continuous as in the case of cranial elements, followed by a period of plateau especially in the case of some defining trophy elements such as length of the rods, length of the eye radius and length of the middle radius.

For age group I NRC element, the number of branches in the crown makes very significant differences.

The CP2, NTR and LRM items, i.e. the circumference of the rod between the eye branch and the middle branch, the total number of spokes and the length of the middle branch achieve distinctly significant differences.

Dmax, the maximum opening of the rods makes a significant difference. Differences for the other elements are insignificant.

As far as age group II is concerned, the differences are insignificant for all trophy elements.

Differences by total sample reveal the following: the NRC and LRO items achieve distinctly significant differences, and the LRM, NTR, and Dmax items achieve significant differences. Differences for the other items are insignificant.

Table 18. Mean values and dispersion indices for trophy items by age group.

Var.	Eastern Carpathians								Curvature Carpathians								Southern Carpathians							
	Group I				Group II				Group I				Group II				Group I				Group II			
	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.
DCF	49,3	4,93	10,00	0,65	53,0	4,44	8,39	0,65	47,5	5,85	12,32	0,75	54,53	3,67	6,72	0,56	48,6	4,36	8,97	0,62	53,1	4,97	9,36	1,14
NRC	8,9	3,19	36,02	0,42	9,2	2,64	28,65	0,39	6,8	2,19	32,01	0,28	8,88	2,21	24,83	0,34	7,5	2,16	28,71	0,31	9,5	2,39	25,08	0,55
Dmax	86,7	11,92	13,76	1,57	89,5	10,82	12,10	1,60	80,1	15,88	19,83	2,05	89,49	12,94	14,45	1,97	82,5	7,90	9,57	1,12	85,1	13,90	16,34	3,19
Dmin	63,7	15,74	24,70	2,07	64,6	17,59	27,21	2,62	61,7	15,95	25,83	2,06	63,57	22,47	35,36	3,43	61,2	12,17	19,88	1,72	56,7	19,16	33,76	4,40
LP	106,5	10,50	9,86	1,38	111,8	7,45	6,66	1,10	101,8	15,07	14,80	1,95	112,1	6,94	6,19	1,06	103,8	7,50	7,23	1,06	109,4	6,71	6,13	1,54
LRO	37,2	7,64	20,53	1,01	40,3	6,62	16,45	0,98	34,8	6,64	19,09	0,86	36,88	7,30	19,78	1,13	33,6	6,30	18,74	0,89	38,0	9,60	25,26	2,20
LRM	35,8	7,73	21,62	1,02	34,4	6,61	19,21	0,98	30,9	7,15	23,16	0,92	35,12	9,04	25,75	1,38	34,2	6,00	17,53	0,85	33,8	8,76	25,93	2,01
RC	24,3	3,34	13,78	0,44	25,1	2,17	8,66	0,32	23,5	2,74	11,66	0,35	25,31	1,76	6,94	0,27	24,2	2,17	8,96	0,31	25,5	2,66	10,43	0,61
CP1	15,3	2,20	14,41	0,29	15,6	1,10	7,03	0,16	14,2	1,90	13,39	0,25	15,91	0,98	6,16	0,15	15,2	2,52	16,53	0,36	15,8	1,18	7,46	0,27
CP2	14,3	1,80	12,62	0,24	14,6	2,46	16,91	0,36	13,5	2,00	14,79	0,26	15,44	1,19	7,72	0,18	14,1	2,36	16,81	0,33	15,1	1,31	8,69	0,30
NTR	14,0	3,41	24,44	0,45	14,4	2,97	20,58	0,44	12,2	2,66	21,83	0,34	14,14	2,67	18,88	0,41	13,1	2,43	18,52	0,34	14,9	2,38	15,97	0,55
GR	7,5	1,77	23,56	0,26	8,5	1,48	17,37	0,25	7,1	2,18	30,69	0,29	9,25	1,57	16,99	0,25	7,8	1,58	20,27	0,25	8,7	1,26	14,37	0,34

Note: Var - items (variables), m - mean, sd - standard deviation, cv% - coefficient of variation, std. er - standard error of means

Table 19. Mean values and dispersion indices for trophy items, per total sample.

Var.	Eastern Carpathians				Curvature Carpathians				Southern Carpathians			
	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.
DCF	50,9	25,4	5,04	9,88	50,4	6,13	12,16	0,60	49,9	4,93	9,88	0,59
NRC	9,0	8,7	2,95	32,74	7,7	2,41	31,33	0,24	8,1	2,38	29,54	0,29
Dmax	87,9	131,8	11,48	13,06	84,0	15,38	18,30	1,52	83,2	9,87	11,86	1,19
Dmin	64,1	272,1	16,50	25,73	62,5	18,87	30,18	1,86	60,0	14,42	24,04	1,74
LP	108,8	92,3	9,61	8,82	106,1	13,31	12,54	1,31	105,3	7,68	7,29	0,92
LRO	38,6	53,7	7,33	19,01	35,7	6,96	19,52	0,69	34,8	7,55	21,68	0,91
LRM	35,2	52,6	7,25	20,63	32,6	8,23	25,21	0,81	34,1	6,80	19,95	0,82
RC	24,6	8,4	2,90	11,79	24,3	2,53	10,43	0,25	24,6	2,36	9,62	0,28
CP1	15,4	3,2	1,80	11,66	14,9	1,79	11,99	0,18	15,4	2,24	14,53	0,27
CP2	14,4	4,5	2,11	14,68	14,3	1,95	13,64	0,19	14,3	2,17	15,10	0,26
NTR	14,2	10,4	3,22	22,71	13,0	2,82	21,73	0,28	13,6	2,53	18,60	0,30
GR	7,9	2,9	1,71	21,57	8,0	2,22	27,80	0,22	8,1	1,55	19,24	0,21

Note: Var - items (variables), m - mean, sd - standard deviation, cv% - coefficient of variation, std. er - standard error of means.

Table 20. Mean values and dispersion indices for trophy items by age group, normalised

Var.	Eastern Carpathians								Curvature Carpathians								Southern Carpathians							
	Group I				Group II				Group I				Group II				Group I				Group II			
	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.
DCF	1,69	0,04	2,56	0,006	1,72	0,04	2,12	0,005	1,67	0,06	3,37	0,007	1,74	0,03	1,65	0,004	1,69	0,04	2,34	0,006	1,72	0,03	1,81	0,007
NRC	0,92	0,16	17,02	0,021	0,95	0,12	12,43	0,017	0,81	0,14	17,71	0,019	0,94	0,11	11,27	0,016	0,86	0,12	14,45	0,018	0,97	0,10	10,37	0,023
Dmax	1,93	0,06	3,16	0,008	1,95	0,05	2,69	0,008	1,89	0,13	7,09	0,017	1,95	0,06	3,29	0,010	1,91	0,04	2,13	0,006	1,92	0,08	3,93	0,017
Dmin	1,79	0,12	6,57	0,015	1,79	0,12	6,71	0,018	1,77	0,12	6,81	0,016	1,77	0,19	10,80	0,029	1,78	0,09	5,11	0,013	1,73	0,17	9,85	0,039
LP	2,03	0,04	2,17	0,006	2,05	0,03	1,45	0,004	2,00	0,07	3,55	0,009	2,05	0,03	1,32	0,004	2,01	0,03	1,57	0,004	2,04	0,03	1,33	0,006
LRO	1,56	0,11	6,93	0,014	1,60	0,07	4,23	0,010	1,53	0,09	5,58	0,011	1,57	0,07	4,76	0,011	1,52	0,09	6,11	0,013	1,56	0,13	8,05	0,029
LRM	1,54	0,10	6,75	0,014	1,53	0,08	5,46	0,012	1,48	0,10	7,07	0,013	1,53	0,11	7,11	0,017	1,53	0,08	5,19	0,011	1,51	0,13	8,83	0,031
RC	1,38	0,06	4,22	0,008	1,40	0,04	2,58	0,005	1,37	0,05	3,84	0,007	1,40	0,03	2,15	0,005	1,38	0,04	2,81	0,006	1,40	0,05	3,25	0,010
CP1	1,18	0,06	4,79	0,007	1,19	0,03	2,57	0,005	1,15	0,06	5,26	0,008	1,20	0,03	2,23	0,004	1,18	0,06	4,85	0,008	1,20	0,03	2,67	0,007
CP2	1,15	0,05	4,77	0,007	1,15	0,17	3,54	0,026	1,13	0,07	6,01	0,009	1,19	0,03	2,83	0,005	1,14	0,06	5,38	0,009	1,18	0,04	3,18	0,009
NTR	1,13	0,11	9,34	0,014	1,15	0,09	7,60	0,013	1,07	0,10	9,14	0,013	1,14	0,08	6,90	0,012	1,11	0,08	7,27	0,011	1,17	0,06	5,30	0,014
GR	0,86	0,11	12,47	0,016	0,92	0,07	8,05	0,013	0,83	0,16	19,37	0,021	0,96	0,07	7,73	0,012	0,88	0,09	10,20	0,014	0,94	0,06	6,76	0,017

Note: Var - items (variables), m - mean, sd - standard deviation, cv% - coefficient of variation, std. er - standard error of means

Table 21. Mean values and dispersion indices for trophy items, per total sample, normalized.

Var.	Eastern Carpathians				Curvature Carpathians				Southern Carpathians			
	m	sd	cv%	er.st.	m	sd	cv%	er.st.	m	sd	cv%	er.st.
DCF	1,705	0,043	2,53	0,004	1,699	0,056	3,30	0,006	1,695	0,040	2,37	0,005
NRC	0,933	0,141	15,10	0,014	0,864	0,143	16,50	0,014	0,889	0,127	14,30	0,015
Dmax	1,940	0,058	2,97	0,006	1,914	0,113	5,93	0,011	1,917	0,052	2,72	0,006
Dmin	1,792	0,118	6,60	0,012	1,772	0,153	8,64	0,015	1,764	0,119	6,75	0,014
LP	2,035	0,040	1,95	0,004	2,022	0,061	3,03	0,006	2,021	0,032	1,59	0,004
LRO	1,577	0,094	5,96	0,009	1,547	0,082	5,33	0,008	1,530	0,104	6,81	0,013
LRM	1,536	0,095	6,20	0,009	1,500	0,109	7,28	0,011	1,523	0,096	6,33	0,012
RC	1,388	0,050	3,61	0,005	1,383	0,047	3,43	0,005	1,388	0,042	3,00	0,005
CP1	1,185	0,047	3,96	0,005	1,170	0,055	4,74	0,005	1,184	0,052	4,38	0,006
CP2	1,148	0,122	4,34	0,012	1,151	0,064	5,53	0,006	1,153	0,058	5,01	0,007
NTR	1,141	0,098	8,60	0,010	1,103	0,096	8,75	0,010	1,126	0,080	7,10	0,010
GR	0,890	0,099	11,12	0,011	0,880	0,147	16,71	0,015	0,898	0,087	9,66	0,012

Note: Var - items (variables), m - mean, sd - standard deviation, cv% - coefficient of variation, er.std - standard error of means.

Table 22. Analysis of variance of trophic elements by age group for the Eastern Carpathians, Curvature Carpathians and Southern Carpathians samples.

Analysis of variance, α =0.05, α =0.01, α =0.001											
Group I						Group II					
Var.	SS	MS	F	p	df	Var.	SS	MS	F	p	df
DCF	0,010	0,005	2,237	0,110^{nes}	2	DCF	0,005	0,003	2,441	0,092^{nes}	2
NRC	0,348	0,174	8,500	0,000***	2	NRC	0,013	0,007	0,546	0,581^{nes}	2
Dmax	0,058	0,029	3,526	0,032*	2	Dmax	0,009	0,005	1,207	0,303^{nes}	2
Dmin	0,007	0,004	0,283	0,754^{nes}	2	Dmin	0,064	0,032	1,236	0,295^{nes}	2
LP	0,015	0,008	2,733	0,068^{nes}	2	LP	0,002	0,001	0,991	0,375^{nes}	2
LRO	0,048	0,024	2,600	0,077^{nes}	2	LRO	0,030	0,015	2,181	0,118^{nes}	2
LRM	0,136	0,068	7,125	0,001**	2	LRM	0,006	0,003	0,278	0,758^{nes}	2
RC	0,007	0,003	1,272	0,283^{nes}	2	RC	0,001	0,000	0,255	0,776^{nes}	2
CP1	0,037	0,019	5,552	0,005**	2	CP1	0,002	0,001	1,213	0,302^{nes}	2
CP2	0,020	0,010	2,625	0,075^{nes}	2	CP2	0,041	0,021	1,502	0,227^{nes}	2
NTR	0,101	0,050	5,437	0,005**	2	NTR	0,008	0,004	0,654	0,522^{nes}	2
GR	0,086	0,043	2,635	0,075^{nes}	2	GR	0,025	0,013	2,373	0,099^{nes}	2

Note: Var - Variable, SS - sum of squares, MS - mean of squares, F - Fisher statistic, p - critical value, df - degree of freedom, * -significant, ** - distinctly significant, ***- highly significant, non-significant.

Table 23. Analysis of variance of trophic elements for the Eastern Carpathians, Curvature Carpathians and Southern Carpathians samples.

Analysis of variance, α =0.05, α =0.01, α =0.001								
Variable	SS	MS	df	SS err.	MS err.	df err.	F	p
DCF	0,005	0,002	2	0,621	0,002	272	1,001	0,369^{nes}
NRC	0,252	0,126	2	5,215	0,019	273	6,593	0,002**
Dmax	0,042	0,021	2	1,842	0,007	273	3,093	0,047*
Dmin	0,037	0,018	2	4,783	0,018	272	1,049	0,352^{nes}
LP	0,012	0,006	2	0,616	0,002	273	2,574	0,078^{nes}
LRO	0,099	0,050	2	2,325	0,009	271	5,776	0,003**
LRM	0,069	0,034	2	2,785	0,010	273	3,358	0,036*
RC	0,002	0,001	2	0,607	0,002	273	0,480	0,620^{nes}
CP1	0,013	0,007	2	0,724	0,003	273	2,497	0,084^{nes}
CP2	0,001	0,000	2	2,176	0,008	273	0,052	0,949^{nes}
NTR	0,073	0,036	2	2,376	0,009	273	4,187	0,016*
GR	0,011	0,005	2	3,283	0,014	230	0,383	0,682^{nes}

Note: SS - sum of squares, MS - mean of squares, SS err - sum of residual squares, MS err - mean of residual squares, df err - residual degree of freedom, F - Fisher statistic, p - critical value, * -significant, ** - distinctly significant, ***- highly significant.

4.3. Research results for objective 3. Correlative study of cranial architecture and trophy as component parts.

The relationship and intensity between the cranial elements of the dorsal, lateral ventral and occipital faces and the trophic elements were revealed by means of simple and multiple correlation analysis, expressed by means of the simple correlation coefficient and the multiple correlation coefficient. Correlation analysis was performed for sample age groups and for the whole sample.

4.3.1. Correlative study of backface elements and trophy elements

Simple correlations between cranial dorsal face elements (15 elements) and trophy elements (12 elements) were performed by age group and sample.

Table 24 shows the simple correlations between trophy elements and cranial dorsal face elements for the Eastern Carpathians.

Analysing these correlations, the following observations can be made: frontal cylinder diameter (DCF) correlates positively and significantly with the maximum width of the nasal bones, a correlation that highlights the symmetry of the frontal region; rod length (LP) correlates positively and significantly with total skull length (P-Op), maximum skull width (Zy-Zy) and maximum width of the frontal bones measured on the orbital rim (Da-Da), thus showing the proportionality and symmetry relationship of the trophy to these bones.

Significant but negative correlations are found between the number of rays in the crown (NRC) and the total number of branches on the rod (NTR) with the width of the neurocranium, with one plausible explanation being structural. This correlation also appears in the analysis of the whole sample, but the correlation coefficient values are lower.

For age group II, when growth and development of the skull is maximal and stable, a number of interesting structural correlations emerge. Thus, for the length of the rods, a significant and inverse correlation can be observed with the length of the neurocranium (Op-Br) and distinctly significant and inverse with the maximum width of the skull (Zy-Zy), suggesting that the ratio of the now stable cranial elements to the variable trophic elements changes over time; the number of branches in the crown (NRC) correlates positively and significantly with the width of the frontal and nasal bones, also suggesting proportionality, the correlation Dmax-Dmin (maximum opening and minimum opening) with the width of the neurocranium. Interesting correlations are made by NRC and NTR, CP2 (circumference of rods between eye ramus and medial ramus) and trophic weight (GR) with maximum frontal bone width. At the sample level, LP correlations with P-Op, P-Br and Zy-Zy are noted showing a well-proportioned structural and functional relationship. Dmax and Dmin, as spatial elements of the trophic, correlate positively and significantly with viscerocranial length, and DCF with Mo-Mo and Nm-Nm as a structural and symmetry relationship.

In addition to simple correlations explaining the relationship between one trophy element and another belonging to the cranial face, multiple correlations were generated in which one trophy element was explained in terms of several cranial elements. The multiple regression method with the *forward stepwise* option was used, from which the largest multiple regression coefficients were chosen, and hence the variables included in the model. This resulted in 7 multiple regression equations for age group I, 10 equations for age group II and 10 equations for the total sample, shown in Table 25.

It can be seen that while in the case of a simple correlation the number of items with significant value is reduced, in the case of multiple regression new links appear, the explicitness of an item being practically modelled by one or more statistically relational items and made explicit by the partial significant coefficients of the regression.

Table 26 shows the simple correlations between trophy elements and cranial dorsal face elements for the Curvature Carpathians.

Analysing these correlations, the following observations can be made: compared to the Eastern Carpathians sample, the Curvature Carpathians show a higher number of correlations, some of which are very significant. For age group I, the DCF element achieves significant correlations with the P-Br, Op-Br, Mo-Mo and Zy-Zy elements. An important positive and significant correlation is recorded between the length of the rods (LP) and the length of the viscerocranium (P-Br), correlation also found for the total sample.

An interesting observation is that the element P-Br achieves significant, distinctly significant and highly significant correlations with many trophy elements in age group I and per total sample, suggesting a specific cohesive and proportional architecture, given that trophy elements, in addition to their role as weapons, can also be a disruptive factor in the process of movement and feeding. The Zy-Zy element, for age group I and per total sample, achieves a significant number of correlations, also suggesting proportionality. The Op-Br item also achieves a significant number of significant correlations for age group I. The maximum trophic aperture achieves two significant and negative correlations with the nasal bone elements, namely their length and width, Ni-Ni and N-Ns. Regarding the number of significant correlations for age group II, it can be seen that it is low compared to group I and the total sample. A plausible reasoning suggests that the variation of cranial elements at older ages is low and relatively stable, while the growth process is continuous and variable.

Among the significant positive correlations, the trophy weight and frontal cylinder diameter items with neurocranial width stand out. Significant negative correlations are made by the NRC and NRT items with the Ect-Ect cranial item, these correlations can be attributed to the fact that while the NRC and NRT values as dependent variables increase (at older ages, the number of radii is higher), the means of the cranial variables decrease.

In addition to simple correlations explaining the relationship between one trophy element and another belonging to the cranial face, multiple correlations were generated in which one trophy element was explained in terms of several cranial elements. The multiple regression method with the *forward stepwise* option was used, from which the largest multiple regression coefficients were chosen, and hence the variables included in the model. This resulted in 9 multiple regression equations for age group I, 9 equations for age group II and 11 equations for the total sample, shown in Table 27.

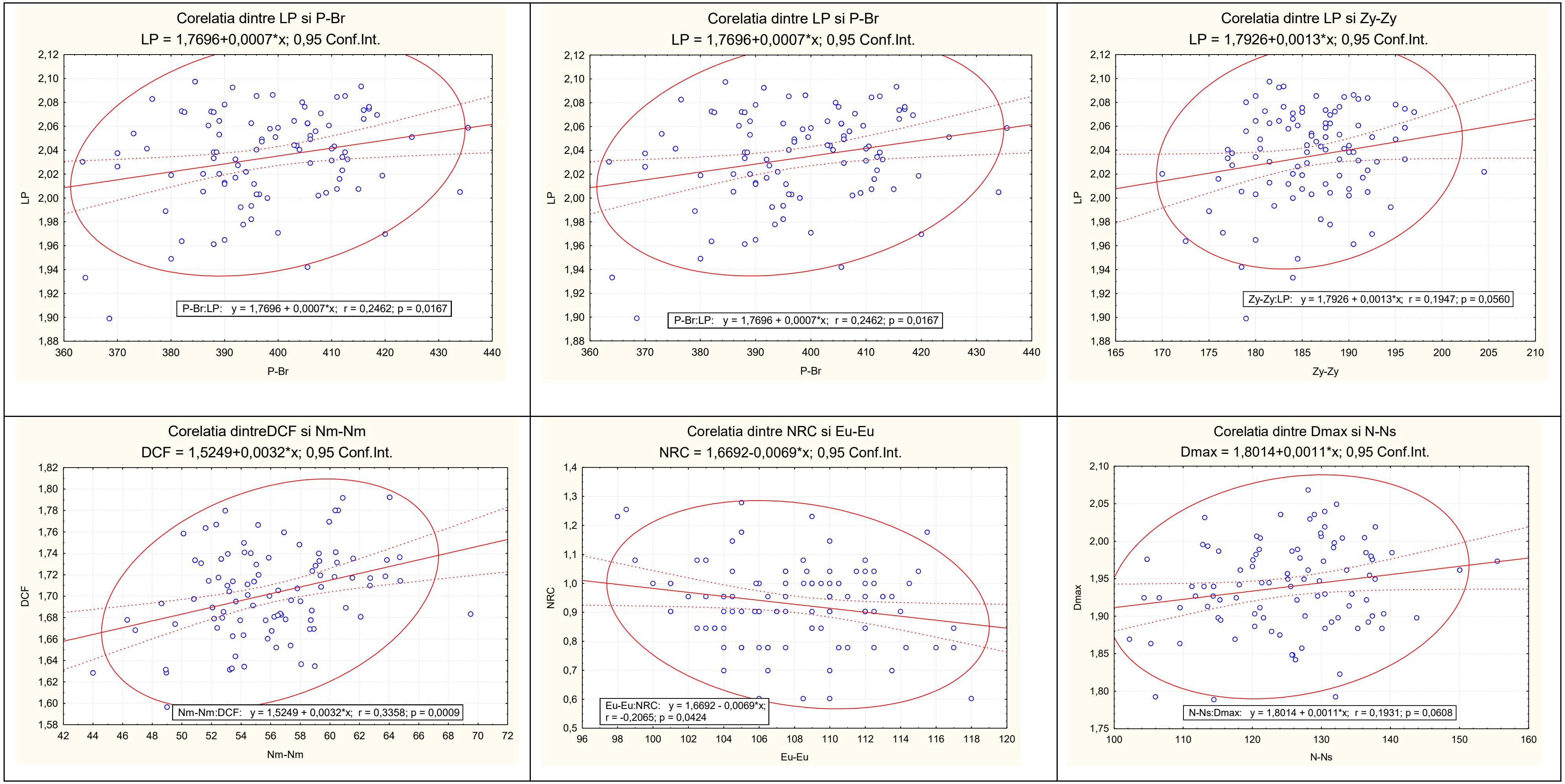

Fig. 25. Regression equations and correlation field, relating trophic and cranial elements for the Eastern Carpathians

Table 25. Simple and multiple regression equations generated between trophic and backface elements for the Eastern Carpathians.

Group	Variable	Rregr.M	pregr.M	Form of regression
I	DCF	0,437	0,021	DCF = 1.54 + 0.37 (Nm-Nm)
	NRC	0,442	0,040	NRC = 1.43 - 0.39(Eu-Eu)
	LP	0,444	0,038	LP = 1.37 + 0.441(P-Op)
	LRO	0,533	0,022	LRO = 2,00 - 0,46 (Eu-Eu)+0,42 (N-Br)
	RC	0,472	0,078	CR = 1,65 + 0,30(Nm - Nm) -0,31(Eu-Eu)
	CP1	0,445	0,074	CP1 = 1,16 - 0,36(N-Br)
	NTR	0,446	0,010	NTR = 1.70 - 0.41(Eu-Eu) +0.33(Sph-Br)
II	DCF	0,714	0,006	DCF= 2.16- 1.2(p-Op)+0.68(Da-Da)-0.64(Zy-Zy)+0.63(N-Ns)- 0.39(St-N)
	NRC	0,460	0,012	NRC= 0.52+0.41(Da-Da)
	Dmax	0,638	0,050	Dmax =2.24-1.15(P-Op)+0.94(P-Br)+0.78(Da-Da) +0.63(Eu-Eu) +0.52(N-Ns)
	Dmin	0,745	0,020	Dmin =1,61+1,33(P-Br)-1,3(P-Op)+0,82(Da-Da)+0,68(Eu-Eu)-0,48(Nm-Nm)
	LP	0,509	0,065	LP= 2,62-0,53(Zy-Zy)-0,38(Eu-Eu)
	LRO	0,710	0,007	LRO = 2.17 -0.63(Ni-Ni) -0.63(Sph-Br) -0.62(Eu-Eu)
	RC	0,620	0,001	CR = 1,68- 0,65(P-Br)+0,47(St-N)+0,36(Da-Da)
	CP1	0,631	0,003	CP1 = 1,32 + 0,98(Ect-Ect) - 0,76(P-Br) + 0,72(N-Br)
	NTR	0,551	0,002	NRT = 1,45 + 0,56(Da-Da) - 0,47(N-Br)
	GR	0,694	0,006	GR = 1,4 +0,68(Da-Da) - 0,52(Zy-Zy)
Total	DCF	0,445	0,002	DCF = 1.57+ 0.37(Nm-Nm) +0.30(Mo-Mo)
	LRO	0,350	0,044	LRO = 1.61 + 0.45(P-Op)
	Dmax	0,402	0,010	Dmax = 1.76 - 0.24(Eu-Eu)
	Dmin	0,224	0,035	Dmin = 1.47 +0.23(N-Ns)
	LP	0,349	0,025	LP = 1.8 - 0.23(Eu-Eu)
	LRO	0,350	0,044	LRO = 1.61 + 0.45(P-Op) -0.24(Eu-Eu)
	LRM	0,350	0,050	LRM = 1.73 + 0.26(Op-Br)
	CP2	0,430	0,016	CP2 = 1.23 - 0.33(Eu-Eu) +0.28(Sph-Br)-0.27(Ect-Ect)
	NTR	0,425	0,010	NTR = 1,74-0,33(Eu-Eu)+0,32(Sph-Br)-0,22(Op-Br)
	GR	0,359	0,025	GR = 0.82 -0.24(Eu-Eu)

Note: $Rregr_{.M}$ - multiple correlation coefficient, $_{pregr.M}$ - probability of regression

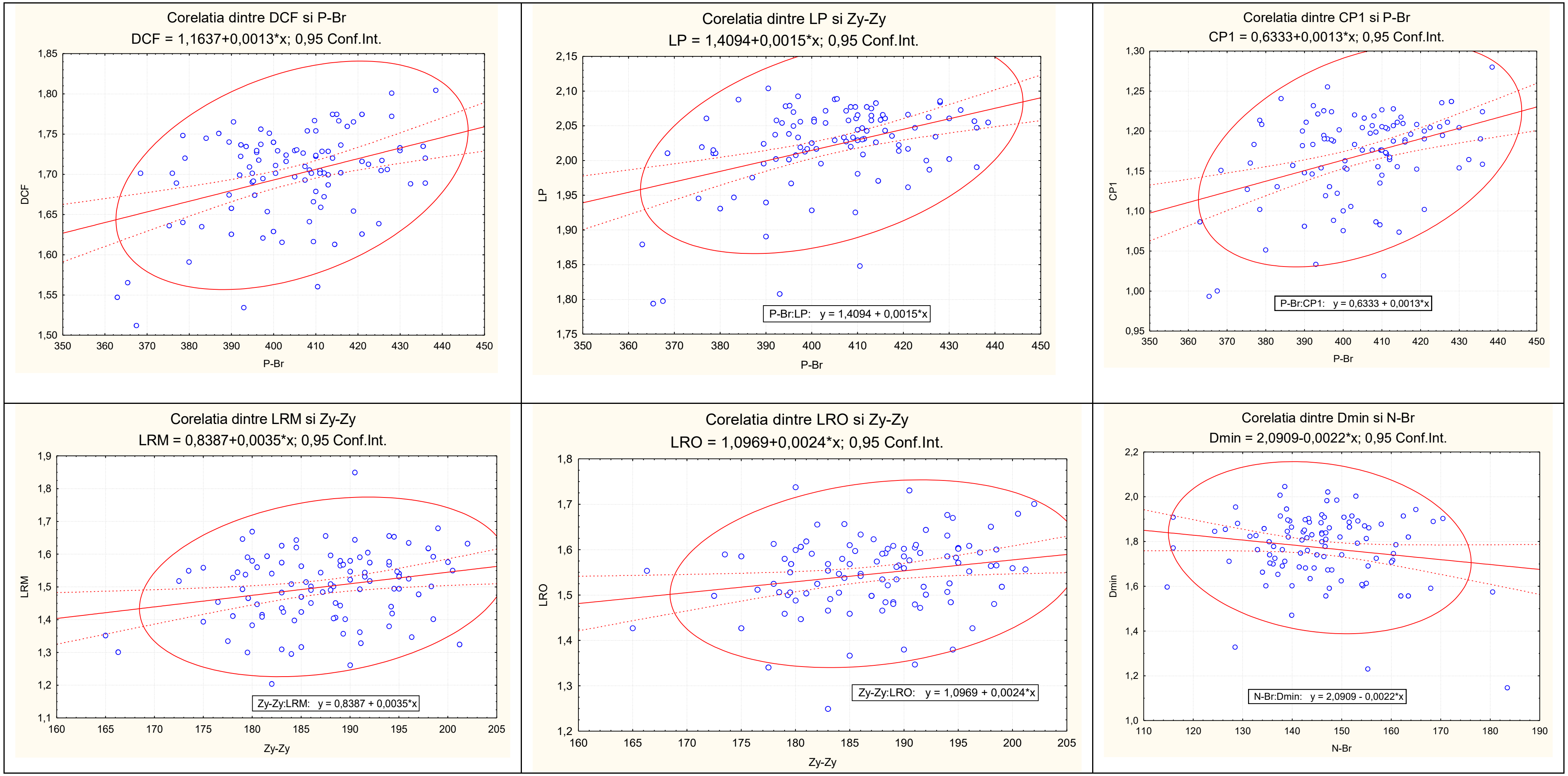

Fig. 26. Regression equations and correlation field, relating trophic and cranial element linkages for the Curvature Carpathians.

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Table 27. Simple and multiple regression equations generated between trophic and backface elements for the Curvature Carpathians.

Group	Variable	Rregr.M	pregr.M	Form of regression
I	DCF	0,634	0,0002	DCF=0,76+0,55(Zy-Zy)+0,34(P-Br)+ 0,29(Op-Br)-0,26(N-Ns)
	NRC	0,602	0,0004	NRC=0,65+0,60(Zy-Zy)-0,31(Ni-Ni)
	Dmax	0,480	0,023	Dmax=1,12+0,42(Zy-Zy)
	LP	0,633	0,0001	LP=0,62+0,44(P-Br)+0,44(Zy-Zy)-0,33(N-Ns)+0,25(Op-Br)
	LRO	0,536	0,001	LRO=0,76+0,42(Zy-Zy)+0,37(Op-Br)-0,47(P-Op)
	RC	0,679	0,0009	CR=0,45+0,38(P-Br)-0,38(N-Ns)+0,35(Zy-Zy)+0,29(Op-Br)
	CP1	0,559	0,0008	CP1=0,15+0,38(P-Br)+0,44(Zy-Zy)
	NTR	0,600	0,0012	NTR=1,01+0,54(Zy-Zy)-0,33(Ect-Ect)-0,31(Ni-Ni)
	GR	0,636	0,001	GR=-2,01+0,53(Zy-Zy)+0,37(P-Br)+0,32(Op-Br)
II	DCF	0,735	0,001	DCF=1,92+0,49(Da-Da)-0,66(P-Op)+0,38(Ni-Ni)+0,36(Eu-Eu)
	NRC	0,408	0,044	NRC=1.12+0.72(Op-Br)
	LP	0,520	0,020	LP=1.96+0.38(Mo-Mo)
	LRO	0,603	0,030	LRO=1,55-0,52(Eu-Eu)+o,42(Ect-Ect)
	LRM	0,462	0,014	LRM=2.31-0.43(P-Br)
	RC	0,586	0,017	CR=1,32+0,56(Ect-Ect)-0,42(Zy-Zy)+0,41(Eu-Eu)
	CP1	0,695	0,002	CP1=1,62-0,58(P-Br)+0,37(Ni-Ni)-0,31(Sph-Br)
	CP2	0,637	0,002	CP2=1,21+0,54(Ect-Ect)+0,54(N-Ns)
	GR	0,623	0,027	GR=0,71-0,58(Da-Da)+0,48(Eu-Eu)
Total	DCF	0,522	0,0000	DCF=0,90+0,36(P-Br)+0,39(Zy-Zy)-0,27(P-Op)
	NRC	0,461	0,019	NRC=-0,39+0,28(P-Br)+0,33(Zy-Zy)-0,22(Ni-Ni)
	Dmax	0,433	0,006	Dmax=0,83+0,39(Zy-Zy)-0,36(Mo-Mo)
	LP	0,551	0,0000	LP=1,04+0,43(Zy-Zy)+0,43(P-Br)
	LRO	0,542	0,002	LRO=0,79-0,51(P-Op)+0,34(Zy-Zy)+0,31(P-Br)+0,30(N-Ns)+0,29(Da-Da)+0,29(Op-Br)
	LRM	0,373	0,0220	LRM=1.09-0.22(Eu-Eu)
	RC	0,588	0,0000	CR=0,80+0,37(Zy-Zy)-0,36(P-Op)+0,37(P-Br)-0,25(Ni-Ni)+0,24(Op-Br)
	CP1	0,532	0,0000	CP1=0,31+0,43(P-Br_-0,30(P-Op)+0,29(Zy-Zy) +0,25(Op-Br)
	CP2	0,510	0,0000	CP2=0,21+0,43(P-Br)-0,34(Zy-Zy)
	NTR	0,459	0,009	NTR=0,27+0,24(P-Br)-0,25(Eu-Eu)
	GR	0,548	0,0000	GR=-1,28+0,44(Zy-Zy)+0,38(P-Br)-0,27(P-Op)+0,20(Op-Br)

Note: Rregr.M - multiple correlation coefficient, pregr.M - probability of regression

Analysing these correlations, the following observations can be made: for age group I there are a significant number of significant, distinctly significant and highly significant correlations. DCF, NRC and Dmax correlate significantly and highly significantly with P-Op and P-Br. The same items correlate significantly and highly significantly with the frontal region and neurocranial items represented by the Fs-Fs, Eu-Eu, Zy-Zy, Ect-Ect and Da-Da items (processes).

The elements CR, Cp1, CP2, NTR and GR make significant and highly significant correlations with the same elements of the frontal region and neurocranium and, in addition, with neurocranial height (Sph). Of note, troph weight correlates with nearly all cranial elements. Another observation is related to the trophic elements that are expressed as lengths, i.e. LP, LRO and LRM, do not correlate significantly with any cranial element, except LP which correlates with P-Br.

For age group II, the number of significant correlations is reduced compared to group I. The LRO element achieves significant correlations with P-Op, Fs-Fs and Eu-Eu, and the

LRM element with P-Op, P-Br, N-Ns and Fs-Fs. Compared to age group I, for the CR, CP2, NTR and GR items all correlations found are not significant.

For the total sample, the DCF element correlates positively and significantly with the Eu-Eu, Mo-Mo, Da-Da and Sph-Br elements, the NRC element with P-Op, P-Br, Mo-Mo, Fs-Fs and St-N, and Dmax with P-Op and P-Br. The LRM, CR, CP1, CP2 elements do not make significant correlations with any of the cranial elements. A number of significant and distinctly significant correlations are made by NTR with P-Br, Mo-Mo, Fs-Fs, Eu-Eu, Zy-Zy and St-N. Positive and distinctly significant correlations are made by GR with P-Br, Ni-Ni, Fs-Fs, Zy-Zy and Sph-Br.

Multiple correlations revealed a significant number of multiple regression equations, 11 for age group I, 12 for age group II and 10 for the total sample.

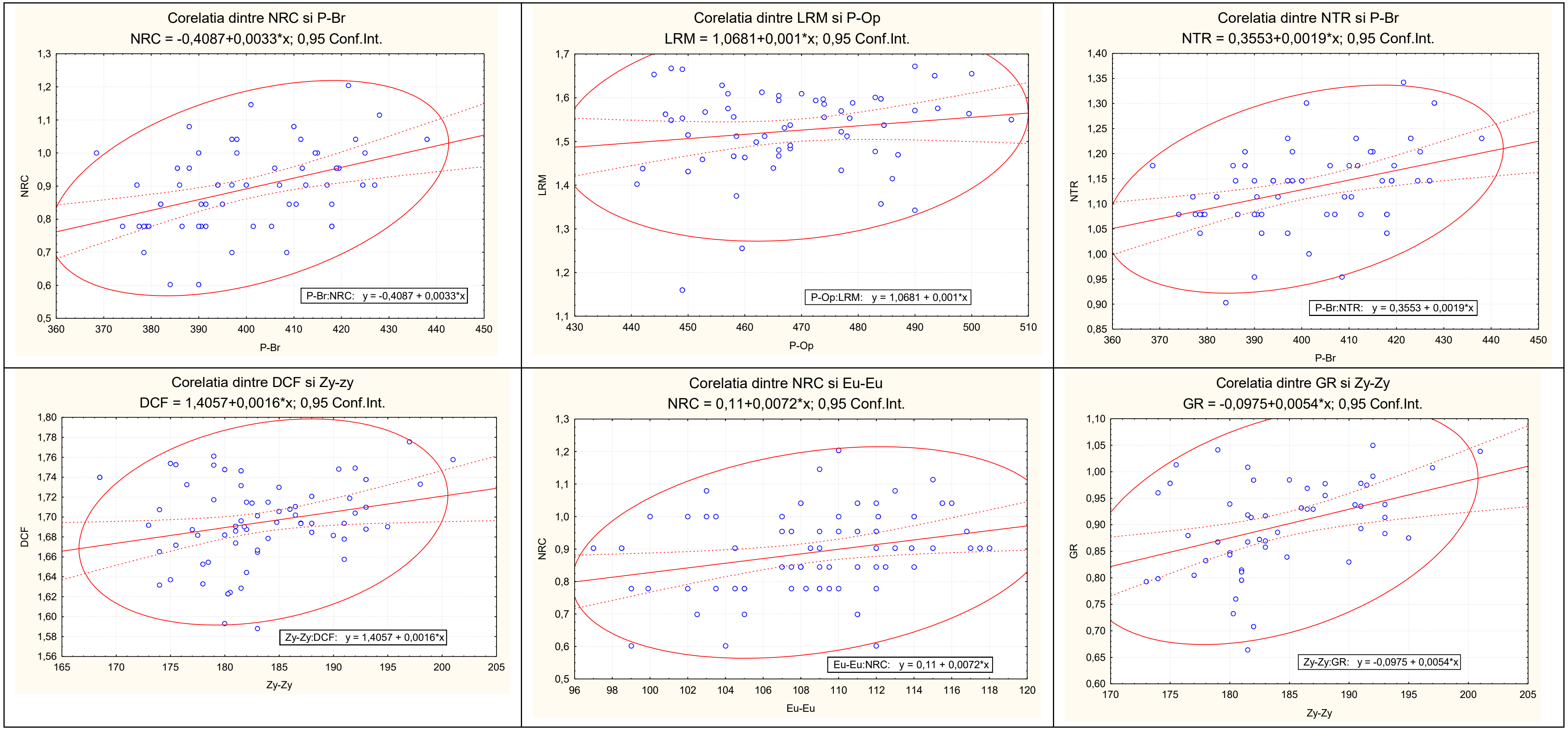

Fig. 27. Regression equations and correlation field, relating trophic elements to cranial dorsal face elements for the Southern Carpathians.

Table 29. Simple and multiple regression equations generated between trophic and backface elements for the Southern Carpathians.

Group	Variable	Rregr.M	pregr.M	Form of regression
I	DCF	0,850	0,0000	DCF=1,01+0,55(Sph-Br)-0,51(Nm-Nm)-0,50(Eu-Eu)+0,32(Ni-Ni) +0,29(P-Br)
	NRC	0,729	0,0003	NRC=-1,21+0,45(P-Br)+0,34(Fs-Fs)-0,34(Op-Br)
	Dmin	0,560	0,037	Dmin=1,03+1,03(P-Op)-0,70(Zy-Zy)
	LP	0,738	0,0006	LP=1,92+1,10(P-Br)-0,52(Nm-Nm)+0,50(Ni-Ni)-0,47(Ect-Ect)+0,38(Sph-Br)
	LRO	0,411	0,0110	LRO=1.61-0.44(Mo-Mo)
	LRM	0,616	0,008	LRM=1,14+0,49(Sph-Br)-0,47(Nm-Nm)+0,36(Fs-Fs)
	RC	0,711	0,001	CR=0,81+0,45(Sph-Br)-0,31(Nm-Nm)
	CP1	0,589	0,003	CP1=0,57+0,41(Ect-Ect)
	CP2	0,611	0,001	CP2=0.44-0.36(P-Op)
	NTR	0,681	0,002	NTR=0,021-0,40(Op-Br)+0,36(Fs-Fs)
	GR	0,865	0,0000	GR=-0,89+0,38(Fs-Fs)-0,37(Nm-Nm)=0,29(Ni-Ni)
II	DCF	0,97	0,0004	DCF=1,13-1,o(P-Br)+0,94(Nm-Nm)+0,63(St-N)+0,41(Eu-Eu)-0,38(Ect-Ect)
	NRC	0,864	0,005	NRC=0,58+0,237(P-Op)-2,7(P-Br)-0,75(Ect-Ect)
	Dmax	0,903	0,0170	Dmax=0,19+1,6(Fs-Fs)+0,64(Sph-Br)-0,64(Ect-Ect)-0,48(Nm-Nm)
	Dmin	0,842	0,0015	Dmin=0,05+1,18(Fs-Fs)-0,71(Zy-Zy)+0,67(Sph-Br)
	LP	0,988	0,0003	LP=1,55+1,88(P-Op)-1,6(P-Br)+1,09(Ni-Ni)-0,93(Mo-Mo)+0,55(Zy-Zy)-0,47(Ect-Ect)-0,23(Nm-Nm)
	LRO	0,837	0,006	LRO= -0,85+1,28(Fs-Fs)-0,82(Zy-Zy)+0,43(Op-Br)
	LRM	0,999	0,002	LRM= -2,13+2,08(P-Op)-1,8(N-Br)+1,7(Ni-Ni)-1,6(Mo-Mo)+0,84(Sph_Br)-0,99(N-Ns)
	RC	0,089	0,0000	CR=0,36+1,41(P-Op)-0,97(Da-Da)-0,66(N-Ns)+0,54(Nm-Nm)+0,60(Eu-Eu)-0,52(Sph-Br)
	CP1	0,999	0,0002	CP1= -1,78-8,6(Mo-Mo)+4,45(N-Br)+3,92(Zy-Zy)+3,96(Op-Br)+2,34(Eu-Eu)+2,34(Fs-Fs)-1,6(Sph-Br)+1,55(P-Br)-0,98(P-Op)-0,92(St-N)-0,37(Nm-Nm)-0,31(N-Ns)
	CP2	0,979	0,012	CP2=1,66-1,7(N-Ns)+1,59(Ni-Ni)-0,75(St-N)-0,61(Nm-Nm)-0,48(Sph-Br)+0,44(Zy-Zy)+0,6(Eu-Eu)
	NTR	0,758	0,008	NTR=0,49-0,83(Ect-Ect)+0,79(Op-Br)+0,76(Nm-Nm)
	GR	0,695	0,005	GR=0,92-0,58(Sph-Br)+0,59(St-N)
Total	DCF	0,499	0,005	DCF=1,30+0,31(Mo-Mo)+0,30(Sph-Br)
	NRC	0,668	0,0000	NRC= -,71+0,37(P-Br)+0,37(Sph-Br)+0,27(Fs-Fs)+0,25(Ni-Ni)
	Dmax	0,608	0,0001	Dmax=1,5+0,75(P-Op)-0,65(Eu-Eu)
	Dmin	0,560	0,003	Dmin=0,53+1,13(P-Op)-0,46(Eu-Eu)-0,39(Mo-Mo)
	LP	0,455	0,059	LP=1,88-0,42(Ect-Ect)
	RC	0,479	0,002	CR=1,19+0,34(Ni-Ni)+0,33(Sph-Br)
	CP1	0,414	0,017	CP1=0.78+0.36(Zy-Zy)
	CP2	0,530	0,0005	CP2=0,84+0,45(Sph-Br)+0,33(Ni-Ni)-0,33(St-N)
	NTR	0,610	0,001	NTR=0,23+0,34(Sph-Br)+0,29(Fs-Fs)
	GR	0,518	0,002	GR=-1.12+0.43(Zy-Zy)

Note: Rregr.M - multiple correlation coefficient, pregr.M - probability of regression

4.3.2. Correlative study of lateral ventral and occipital face elements and trophy elements.

Simple correlations by age group and sample were made between the cranial elements of the ventral, lateral and occipital face (13 elements) and the trophic elements (12 elements).

Table 30 shows the simple correlations between trophy elements and cranial elements of the ventral, lateral and occipital face for the Eastern Carpathians.

Regarding the correlations of age group I, it is observed that there is only one significant correlation between pole length and maximum occipital face height (Ot-Ot), the other correlations being insignificant.

For age group II, the correlations are low. There is a significant correlation between rod length and lateral viscerocranial length (Zl-P). Rosette circumference correlates significantly and negatively with Zl-P, and CP1 and CP2 significantly and negatively with upper jaw tooth row length (Pm-Pd). CP2 also correlates significantly and positively with skull base length (P-B).

For the whole sample, there are significant positive correlations between Dmax and P-B, P-O and Pm-Pd. Rod length achieves significant correlations with P-B, P-O, St-P, Zl-P and Ot-Ot, these correlations actually show the proportional relationship between rod length and ventral, lateral and occipital faces as a whole. NRC and NTR correlate significantly with Op-O.

Although the number of simple correlations is small, the multiple correlation of the elements of the two age groups and the total sample revealed a significant number of multiple regression equations performed between the trophy elements and the cranial face elements: 7 for age group I, 9 for age group II and 9 for the total sample. The form of these multiple regressions is shown in Table 31.

Table 32 shows the correlations established between the trophy elements and the elements of the ventral, lateral and occipital faces, the Curvature Carpathians sample. For age group I, with the exception of elements Dmax and Dmin, all trophy elements correlate significantly, distinctly significantly and highly significantly with cranial elements P-B, P-O, St-P, Mol-P and Pm-P. There are also correlations between the trophy elements and the cranial elements Zl-P and Ot-Ot. There are no significant correlations between the trophy elements and the cranial elements represented by the processes Pm-Pd, M-M, Zl-Op, Con-Con and Op-O.

For age group II and for the total sample, the table of significant, distinctly significant and highly significant correlations is almost identical (Table 32).

In terms of multiple correlation, there are a significant number of regressions, i.e. 7 for group I, 9 for group II and 8 for the whole sample (Table 33).

For the Southern Carpathians sample (Table 34), age group I, the DCF, NRC and Dmax elements achieve significant correlations with the ventral face structural elements P-B, P-O, St-B, Pm-P, respectively, also registering significant and distinctly significant correlations with the lateral face and occipital face elements, Zl-P, Ot-Ot, respectively.

LP, LRM, LRO and Dmin elements expressing basically lengths of trophic components do not achieve any significant correlation with cranial face elements, except for a significant inverse correlation respectively, LRM with Op-O. Trophy weight correlates with ventral, lateral and occipital face structural elements.

For age group II, the DCF, NRC, Dmax and Dmin elements do not correlate significantly with the cranial elements of the ventral, lateral and occipital faces, except for the NRC and Dmax elements which correlate significantly with Pm-Pd. For the length, LP correlates with St-P, LRO with Zl-Op, and with elements of the occipital face respectively Ot-Ot and Con-Con.

The circumference of the CR rosette correlates with Ot-Ot and NTR with P-B. For this group, the weight correlates with a single element of the ventral face respectively, P-O. For the total sample, the number of significant correlations is relatively low. The total number of rays in the crown correlates significantly and distinctly significantly with the structural elements of the ventral face, a single correlation with the lateral and occipital face. The LP, LRM and LRO elements representing rod length, eye ray length and mid-ray length, rod circumferences, CP1, CP2 and CR rosette circumference, do not correlate significantly with any element of the ventral, lateral and occipital faces.

The total number of branches, NTR, achieves significant and distically significant correlations with ventral face elements, one lateral face element and one occipital face element. Trophy weight correlates with three ventral face elements, one lateral face element and one occipital face element.

In terms of multiple correlation, there are a significant number of regressions, namely 10 for group I, 9 for group II and 10 for the whole sample (Table 35).

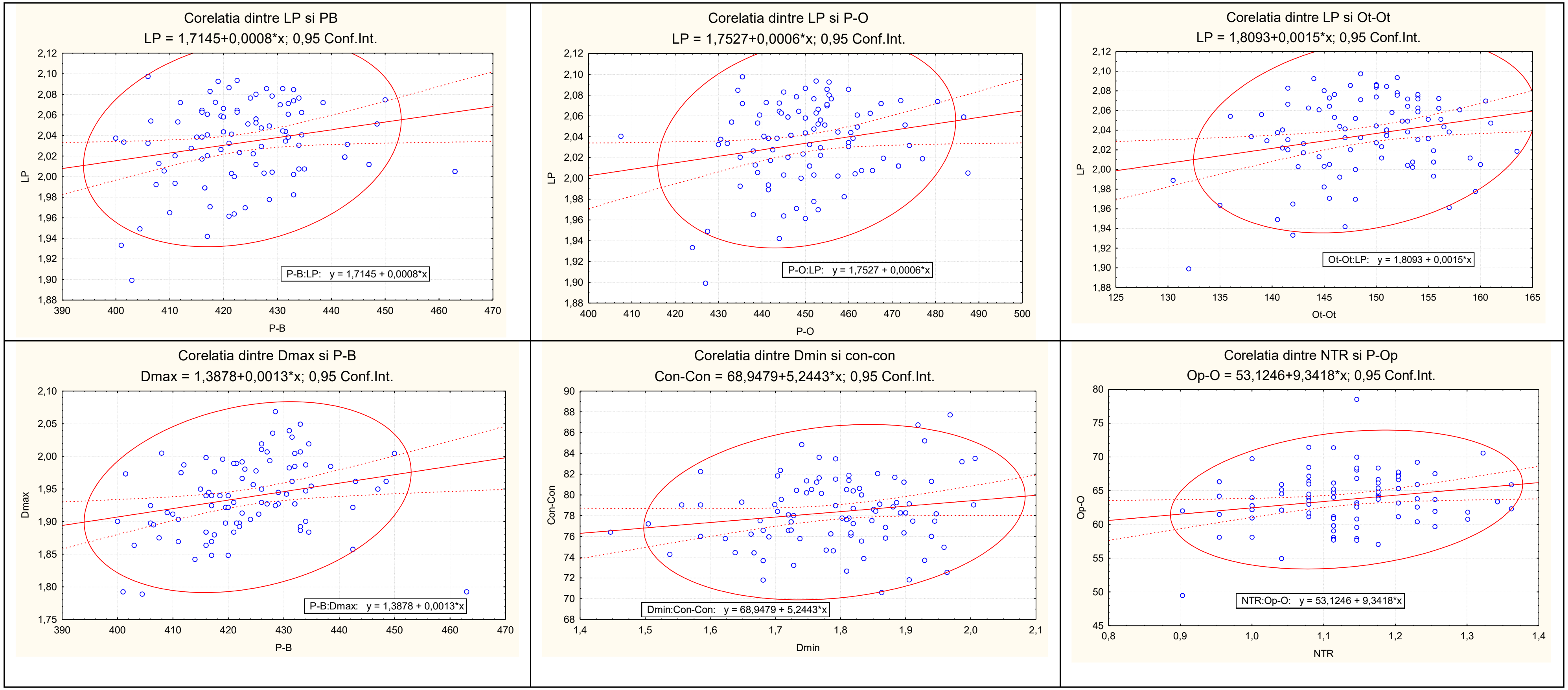

Fig. 28. Regression equations and correlation field, relating trophic elements to cranial elements of the lateral ventral and occipital faces for the Eastern Carpathians.

Table 31. Simple and multiple regression equations generated between trophic elements and lateral ventral and occipital face elements for the Eastern Carpathians.

Group	Variable	Rregr.M	pregr.M	Form of regression
I	DCF	0,39	0,002	DCF=1.16+0.42(Ot-Ot)
	NRC	0,43	0,059	NRC=1.17-0.51(St-P)
	Dmin	0,664	0,001	Dmin=0,66-1,7(P-B)+1,25(P-O)
	LP	0,398	0,03	LP=1.5+0.310(Ot-Ot)
	RC	0,438	0,146	CR=1,16+0,64(Ot-Ot)-0,34(M-M)
	CP1	0,455	0,111	CP1=0,73+0,39(Ot-Ot)+0,30(Zl-P)
	CP2	0,434	0,085	CP2=0,78+0,515(Ot-Ot)
II	DCF	0,739	0,013	DCF=1,4+0,7(P-B)-0,57(P-O)-0,53(Zl-Op)
	Dmin	0,821	0,0007	Dmin=2,10-0,41(St-B)+0,46(Con-Con)
	LP	0,613	0,0045	LP=1,97-0,83(Mo-P)-0,61(Pe-P)
	LRO	0,512	0,0800	LRO=1.91-0.45(Ot-Ot)
	LRM	0,380	0,0060	LRM=2.18-0.54(Zl-Op)
	RC	0,505	0,022	CR=1.65-0.78(Zl-Op)
	CP1	0,341	0,041	CP1=1.45-0.34(Pm-Pd)
	NTR	0,588	0,020	NTR=1,77-0,48(Zl-P)+0,35(Pm-P)
	GR	0,692	0,042	GR=0,10-0,73(Zl-Op)-0,42(Pm-Pd)
Total	NRC	0,413	0,020	NRC=0,75+0,324(Pm-P)+0,29(Op-O)
	Dmax	0,326	0,009	Dmax=1.08+0.27(P-B)
	Dmin	0,389	0,041	Dmin=1,16+0,50(P-O)-0,39(Mol-P)
	LP	0,400	0,014	LP=1,33+0,2(Zl-P)=0,25(Ot-Ot)
	LRO	0,267	0,108	LRO=0.33+0.21(Zl-P)
	RC	0,345	0,034	CR=1,31+0,35(Ot-Ot)-0,32(St-B)
	CP1	0,385	0,01	CP1=0,74-0,36(St-B)+0,32(Ot-Ot)+0,25(Zl-P)
	CP2	0,388	0,003	CP2=0,81+0,44(Ot-Ot)-0,34(St-B)
	NTR	0,311	0,008	NTR=0,08+0,24(Zl-P)+0,26(Op-O)

Note: $Rregr_{.M}$ - multiple correlation coefficient, $_{pregr.M}$ - probability of regression

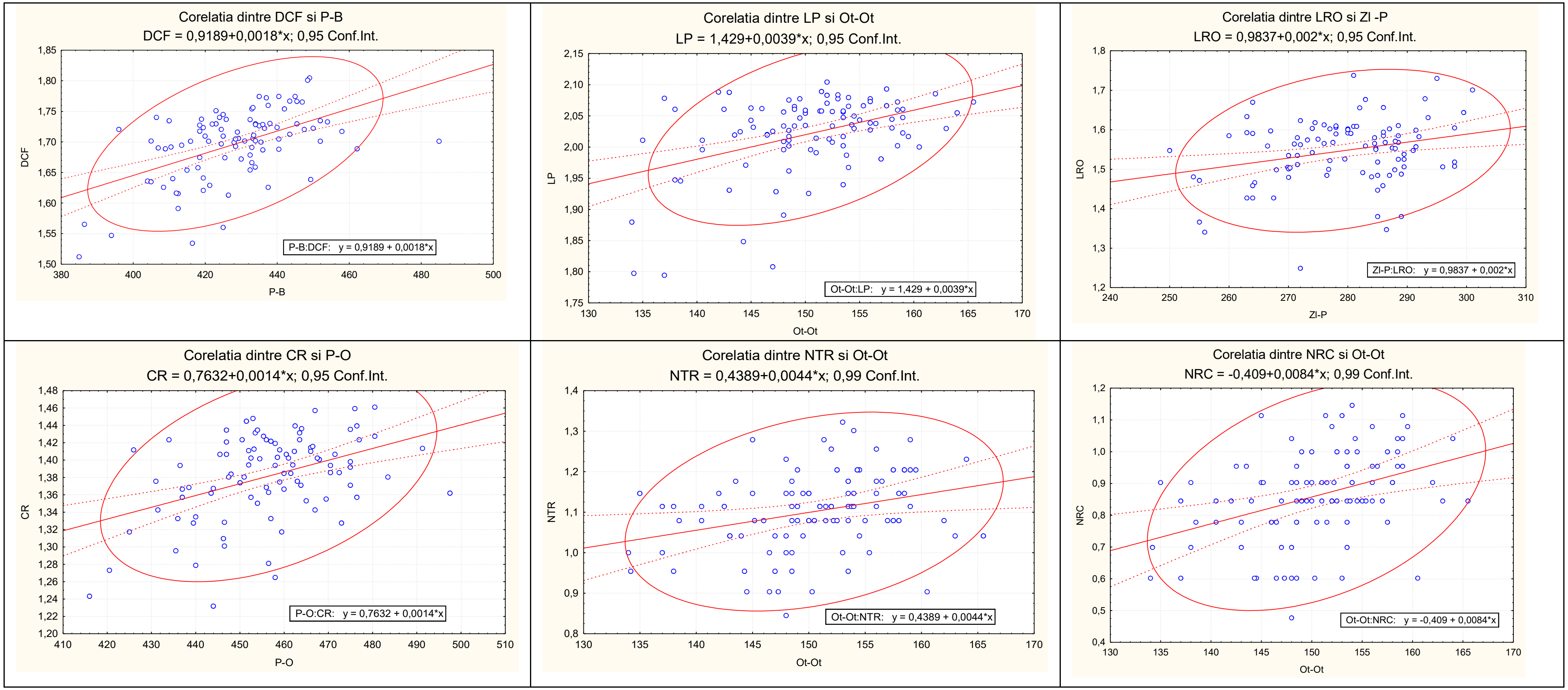

Fig. 29. Regression equations and correlation field, relating trophic elements to cranial elements of the lateral ventral and occipital faces for the Curvature Carpathians.

Table 33. Simple and multiple regression equations generated between trophic elements and ventral, lateral and occipital face elements for the Curvature Carpathians.

Group	Variable	Rregr.M	pregr.M	Form of regression
I	NRC	0,420	0,003	NRC=-0,33+0,30(Op-O)-0,33(Pm-P)-0,29(P-B)
	Dmin	0,389	0,040	Dmin=1,16+0,51(P-O)-0,39(Mol-P)
	LP	0,616	0,000	LP=0.79+0.89(P-B)
	RC	0,340	0,034	CR=1,31+0,35(Ot-Ot)-0,32(St-B)
	CP1	0,385	0,010	CP1=0,74+0,32(Ot-Ot)-0,36(St-B)+0,25(Zl-P)
	CP2	0,388	0,003	CP2=0,81-0,44(Ot-Ot)-0,34(St-B)
	NTR	0,433	0,009	NTR=0,20+0,29(Op-O)+0,24(Zl-P)
II	DCF	0,685	0,010	DCF=0,51+0,94(P-B)-0,39(Ot-Ot)
	NRC	0,566	0,0006	NRC=-1,08+0,40(St-B)+0,40(Ot-Ot)-0,34(Zl-P)
	Dmax	0,391	0,070	Dmax=1,26+0,41(Pm-P)-0,46(Mol-P)
	LP	0,610	0,0000	LP=0.79+0.89(P-B)
	RC	0,582	0,0000	CR=0,40+0,71(P-B)-0,48(Zl-P)
	CP1	0,702	0,0000	CP1=0,014+0,96(P-B)-0,79(Zl-P)+0,31(Ot-Ot)
	CP2	0,730	0,0000	CP2=-0,24+1,04(P-B)-0,64(Zl-P)
	NTR	0,359	0,001	NTR=-0,26+0,33(St-B)-0,37(Zl-P)
	GR	0,655	0,0007	GR=-2,51+0,76(P-B)+0,46(St-P)+0,34(Ot-Ot)
Total	DCF	0,637	0,0000	DCF=0,78+0,36(Ot-Ot)+0,20(St-B)
	NRC	0,584	0,0000	NRC=-0,77=0,37(Ot-Ot)+0,39(St-B)+0,26(Pm-P)
	Dmin	0,341	0,0230	Dmin=0,86-0,27(Mol-P)-,24(St-B)
	LP	0,547	0,0000	LP=1,96+0,25(Ot-Ot)+0,22(St-B)
	CP1	0,587	0,0000	CP1=0,25+0,42(Ot-Ot)+0,23(St-B)
	CP2	0,615	0,0000	CP2=0,02+0,38(P-B)+0,36(Ot-Ot)+0,19(St-B)
	NTR	0,487	0,0001	NTR=0,033+0,35(St-B)+0,25(Ot-Ot)+0,27(Pm-P)
	GR	0,608	0,0000	GR=-1,67+0,36(Ot-Ot)+0,20(St-B)

Note: $Rregr_{.M}$ - multiple correlation coefficient, $_{pregr.M}$ - probability of regression

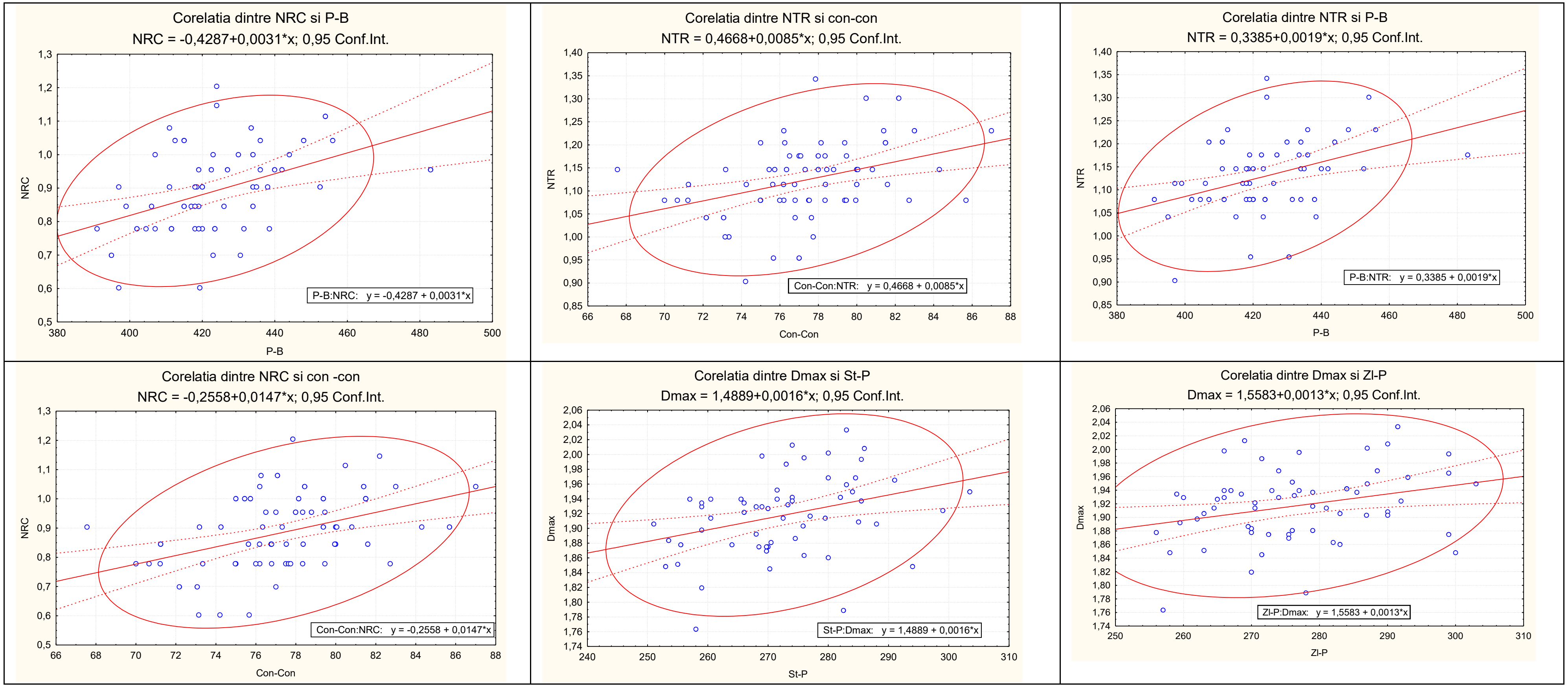

Fig. 30. Regression equations and correlation field, relating trophic elements to cranial elements of the lateral ventral and occipital faces for the Southern Carpathians.

Table 35. Simple and multiple regression equations generated between trophic elements and lateral ventral and occipital face elements for the Southern Carpathians.

Group	Variable	$Rregr._M$	$pregr._M$	Form of regression
I	DCF	0,575	0,004	DCF=1,06+0,41(M-M)+0,36(P-O)
	NRC	0,579	0,0002	NRC=-8,74+0,37(Con-Con)
	Dmax	0,551	0,002	Dmax=1,40+0,84(P-O)-0,41(St-B)
	LP	0,323	0,034	LP=1.78+0.32(Zl-P)
	LRO	0,417	0,001	LRO=1.52-0.41(Pm-P)
	LRM	0,523	0,001	LRM=1,77+0,66(Mol-P)-0,62(Pm-P)+0,48(Con-Con)-0,46(Ot-Ot)
	RC	0,636	0,007	CR=0,86+0,76(Zl-P)+0,34(M-M)
	CP1	0,458	0,008	CP1=1.08+0.44(M-M)
	CP2	0,415	0,005	CP2=0.64+0.41(M-M)
	GR	0,66	0,002	GR=-1,11+0,41(Con-Con)-0,45(Op-O)
II	DCF	0,987	0,025	DCF=1,18+2,26(Ot-Ot)+0,72(Op-O)-0,61(P-B)
	NRC	0,798	0,005	NRC=-0,73+0,73(Pm-Pd)+0,47(St-B)
	Dmin	0,664	0,064	Dmin=-2.49+0.73(M-M)
	LRO	0,951	0,0000	LRO=1,40+0,96(Ot-Ot)-0,44(Pm-Pd)-0,32(Mol-P)
	LRM	0,931	0,001	LRM=-2,88+0,92(Ot-Ot)-0,75(M-M)+0,50(Pm-Pd)
	RC	0,669	0,050	CR=1.72+0.75(Ot-Ot)
	CP1	0,520	0,038	CP1=0.62+0.52(Mol-P)
	CP2	0,678	0,2020	CP2=1.18+1.36(Zl-P)
	GR	0,799	0,035	GR=-0.03+1.54(P-O)
Total	NRC	0,534	0,001	NRC=-0,92+0,32(Mol-P)
	Dmax	0,661	0,000	Dmax=1,18+1,03(P-B)-0,52(Ot-Ot)-0,51(St-B)
	Dmin	0,461	0,002	Dmin=0,35+0,58(P-B)-0,42(Ot-Ot)
	LP	0,296	0,025	LP=1.79+0.29(P-B)
	LRO	0,543	0,039	LRO=1.72-0.72(Pm-P)
	LRM	0,425	0,031	LRM=0.88-0.40(Ot-Ot)
	RC	0,730	0,018	CR=1.08+0.319Op-O)
	CP1	0,399	0,025	CP1=0.93+0.33(M-M)
	CP2	0,447	0,038	CP2=0.91+0.45(M-M)
	GR	0,498	0,03	GR=-0.12+0.31(M-M)

Note: $Rregr._M$ - multiple correlation coefficient, $pregr._M$ - probability of regression

4.4. Research results for objective 4. Comparative study of the three samples in terms of age group and interpopulation variability using the multivariate statistical technique.

Differences between the samples and age groups taken in the study, by analysing its elements and choosing those with discriminatory power and degree of participation were revealed by means of discriminant analysis, the "forward stepwise" method applied to the cranial faces and the trophy.

4.4.1 Discriminant analysis for the dorsal face, age group I

The 15 elements of the age backbone faces were introduced into the analysis and the results are shown in Table 36.

Table 36. Discriminant function for age group I, Eastern Carpathians, Curvature Carpathians and Southern Carpathians.

N=148	Wilks' Lambda	Partial Lambda	F-remove (2,137)	p-level	Tolerate.	1-Tolerate. (R-Sqr.)
Ect-Ect	0,7396	0,8747	9,8158	0,0001	0,4618	0,5382
Op-Br	0,6929	0,9336	4,8691	0,0091	0,8374	0,1626
Da-Da	0,6875	0,9410	4,2964	0,0155	0,4845	0,5155
Nm-Nm	0,6787	0,9531	3,3690	0,0373	0,8082	0,1918
Ni-Ni	0,6673	0,9694	2,1625	0,1189	0,6827	0,3173
Zy-Zy	0,6726	0,9618	2,7217	0,0693	0,4286	0,5714
St-N	0,6661	0,9711	2,0357	0,1345	0,7549	0,2451
Mo-Mo	0,6655	0,9721	1,9652	0,1441	0,4508	0,5492
Fs-Fs	0,6645	0,9735	1,8656	0,1587	0,7448	0,2552

Of the 15 variables introduced into the analysis, only nine were entered into the model. The Partial Lambda estimator determined that only four variables, namely Ect-Ect, Op-Br, Da-Da and Nm-Nm had discriminatory power, in other words these four variables contributed significantly, in the order indicated, to the differentiation of the three samples, the other five variables in the model having an insignificant role. The variables P-Op, P-Br, N-Ns, Eu-Eu and Sph, were not entered in the model.

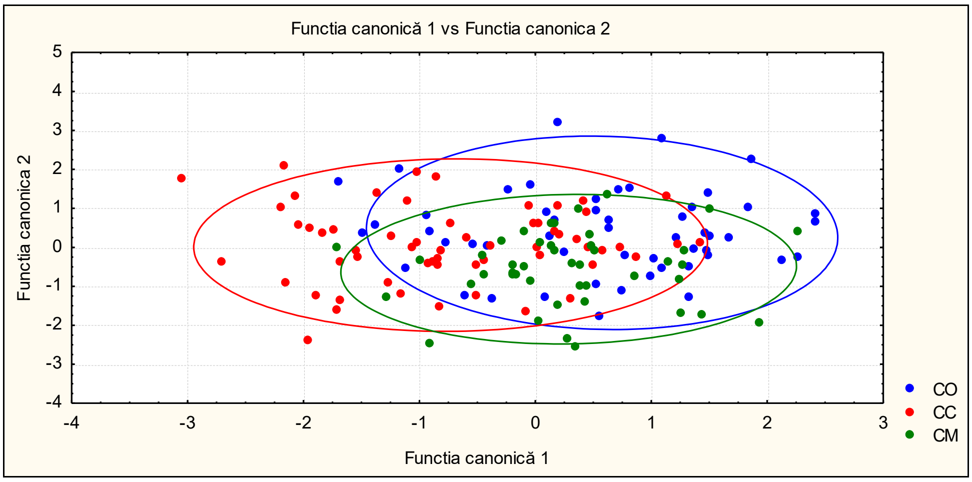

Fig. 31. Canonical score chart for age group I.

Table 38. Classification of functions by sample

Variable(s)	CO	CC	CM
	p=0,33784	p=0,37838	p=0,28378
Ect-Ect	0,162	0,313	0,186
Op-Br	0,378	0,465	0,376
Da-Da	-0,322	-0,425	-0,422
Nm-Nm	0,039	0,026	0,140
Ni-Ni	-1,303	-1,168	-1,205
Zy-Zy	2,804	2,701	2,705
St-N	2,113	2,191	2,105
Mo-Mo	-0,210	-0,234	-0,094
Fs-Fs	2,387	2,376	2,459
Constant	-509,179	-520,339	-508,505

Another important aspect is the ranking of the functions of the variables (items) within the groups shown in Table 38, which, through its positive and negative indices, shows the score obtained by each item, providing clues on the ranking of the cases.

Table 39. Estimated classification and observed classification for dorsal face age group I.

Group	Percent estimated %	CO p=0,33784	CC p=,037838	CM p=0,28378
CO	63,46154	33	11	8
CC	66,10169	16	39	4
CM	45,45454	15	9	20
TOTAL	59,35484	64	59	32

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM- Southern Carpathians.

The result of the analysis is shown in Table 39 where the estimated classification matrix was made proportional to the number of cases, percentage by group.
It can be seen that for age group I of the dorsal face in the case of the Eastern Carpathians the estimated classification is 63.46% with 33 cases classified correctly and 19 incorrectly, the Curvature Carpathians with 66.10% with 39 cases classified correctly and 20 incorrectly, and the lowest estimate is the Southern Carpathians with 45.45% respectively 20 cases classified correctly and 24 incorrectly.
The estimated percentage for the total experiment is 59.35%.

4.4.2 Discriminant analysis for the dorsal face, age group II

The 15 elements of the age dorsal face were entered into the analysis and the results are shown in Table 40.

Table 40. Discriminant function for age group II, Eastern Carpathians, Curvature Carpathians and Southern Carpathians.

N=94	Wilks' Lambda	Partial Lambda	F-remove (2, 83)	p-level	Tolerate.	1-Tolerate. (R-Sqr.)
Ect-Ect	0,6303	0,8179	9,2386	0,0002	0,4508	0,5492
Mo-Mo	0,5878	0,8770	5,8228	0,0043	0,5462	0,4538
P-Br	0,5700	0,9044	4,3887	0,0154	0,6917	0,3083
Fs-Fs	0,5755	0,8958	4,8259	0,0104	0,6108	0,3892
Zy-Zy	0,5437	0,9482	2,2664	0,1101	0,3222	0,6778
Op-Br	0,5520	0,9339	2,9388	0,0585	0,7195	0,2805
Da-Da	0,5398	0,9550	1,9533	0,1483	0,4080	0,5920
Sph-Br	0,5514	0,9348	2,8926	0,0610	0,7303	0,2697
N-Br	0,5368	0,9604	1,7116	0,1869	0,7735	0,2265

Of the 15 variables entered into the analysis only nine of these were entered into the model. The Partial Lambda estimator determined that only four variables, namely Ect-Ect, Mo-Mo, P-Br and Fs-Fs, had discriminatory power, in other words the four variables contributed significantly, in the order indicated, to the differentiation of the three samples, the other five variables in the model having an insignificant role. The variables P-Op, N-Ns, Eu-Eu, Ni-Ni and St-N, were not included in the model.

Analysing the means of the canonical variables shows that the canonical function 1 differentiates somewhat the group I of the Curvature Carpathians from the Eastern Carpathians and the Southern Carpathians. Canonical function 2 shows a differentiation between the

Southern Carpathians, the Curvature Carpathians and the Eastern Carpathians. The graphical representation is shown in Figure 32.

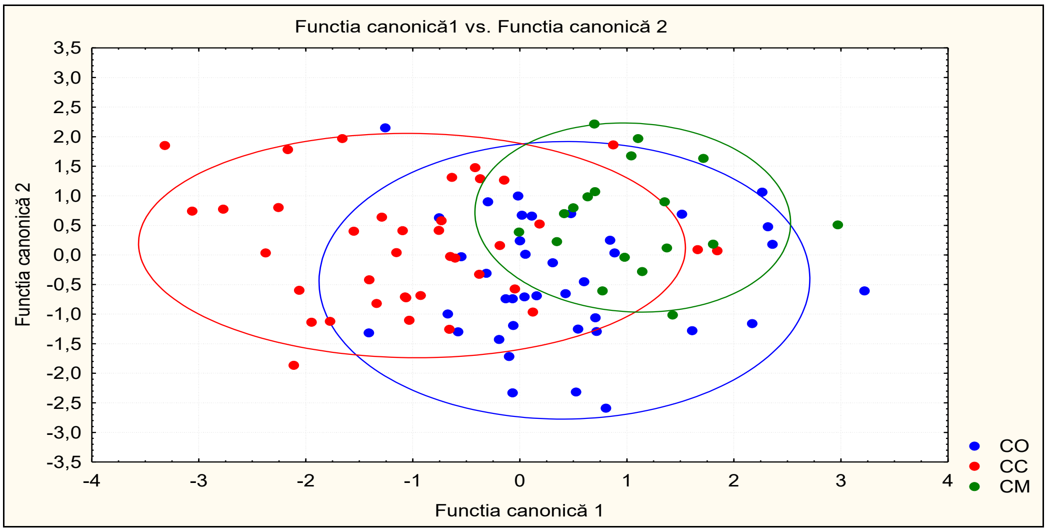

Fig. 32. Canonical score chart for age group II.

Table 42. Classification of functions by sample

Variable(s)	CO	CC	CM
	p= 0,41489	p= 0,39362	p=0,19149
Ect-Ect	-0,260	-0,078	-0,244
Mo-Mo	-1,744	-1,858	-1,502
P-Br	1,668	1,730	1,659
Fs-Fs	1,633	1,531	1,773
Zy-Zy	3,549	3,557	3,372
Op-Br	1,522	1,630	1,548
Da-Da	-1,291	-1,409	-1,352
Sph-Br	1,921	1,825	2,028
N-Br	0,199	0,230	0,162
Constant	-790,279	-815,711	-796,006

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM- Southern Carpathians.

Another important aspect is the ranking of the functions (items) within the groups shown in Table 42, which through its positive and negative indices shows the score obtained by each item, giving clues on the ranking of the cases.

Table 43. Estimated classification and observed classification for dorsal face age group II.

.Group	Estimated percentage%	CO p=0,3378	CC p=0,3783	CM p=0,2837
CO	66,6666	26	8	5
CC	78,9473	7	30	1
CM	44,4444	10	0	8
TOTAL	67,3684	43	38	14

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM- Southern Carpathians.

The result of the analysis is shown in Table 43, where the estimated classification matrix, as a percentage of the cases by group, was made in proportion to the number of cases.

It can be seen that for the second age group of the dorsal face in the case of the Eastern Carpathians the estimated classification is 66.94% with 26 cases classified correctly and 14 incorrectly, the Curvature Carpathians with 78.10% with 30 cases classified correctly and 8 incorrectly, and the lowest estimate is the Southern Carpathians with 44.44% respectively 10 cases classified correctly and 18 incorrectly.

4.4.3 Discriminant analysis for dorsal face, per total samples

The 15 elements of the age backbone faces were entered into the analysis, the results are shown in Table 44.

Table 44. Discriminant function for total samples, Eastern Carpathians, Curvature Carpathians and Southern Carpathians.

N=242	Wilks' Lambda	Partial Lambda	F-remove (2,232)	p-level	Tolerate.	1-Tolerate. (R-Sqr.)
Ect-Ect	0,800585	0,837795	22,45876	0,000000	0,464680	0,535320
Da-Da	0,700034	0,958134	5,06871	0,007005	0,462832	0,537168
Op-Br	0,717706	0,934542	8,12499	0,000389	0,828735	0,171265
Fs-Fs	0,701550	0,956063	5,33097	0,005450	0,716131	0,283869
Mo-Mo	0,709526	0,945316	6,71027	0,001469	0,554859	0,445141
Zy-Zy	0,697829	0,961161	4,68734	0,010101	0,404171	0,595829
P-Br	0,696102	0,963546	4,38871	0,013464	0,877210	0,122790
Nm-Nm	0,685268	0,978779	2,51498	0,083068	0,781460	0,218540

Of the 15 variables entered into the analysis, only eight were entered into the model. The Partial Lambda estimator determined that the discriminatory power of seven variables, namely Ect-Ect, Da, Op-Br and Fs-Fs, in other words the seven variables contributed significantly, in the order indicated, to the differentiation of the three samples, with the variable Nm-Nm in the model playing an insignificant role. The variables P-Op, P-Br, N-Ns, Eu-Eu, Ni-Ni, Sph-Br and St-N, were not entered into the model.

Analysing the means of the canonical variables shows that the canonical function 1 differentiates somewhat the group I of the Curvature Carpathians from the Eastern Carpathians and the Southern Carpathians. Canonical function 2 shows a differentiation between the Southern Carpathians, the Curvature Carpathians and the Eastern Carpathians. The graphical representation is shown in Figure 33.

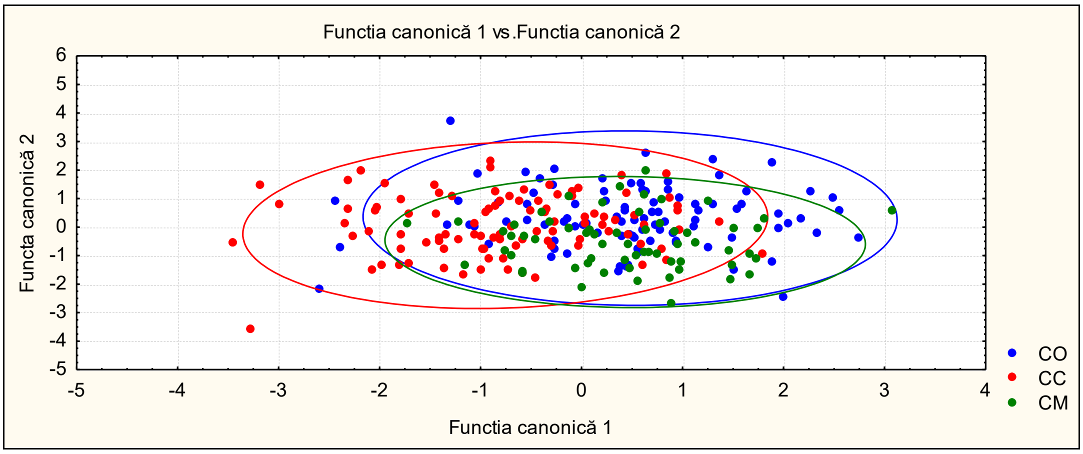

Fig. 33. Canonical score plot by total samples.

Table 46. Classification of functions by sample

Variable(s)	CO	CC	CM
	p= 0,3677	p=0,3843	p=0,2479
Ect-Ect	0,222	0,391	0,257
Da-Da	-0,315	-0,403	-0,403
Op-Br	0,957	1,051	0,973
Fs-Fs	1,847	1,807	1,929
Mo-Mo	-0,864	-0,881	-0,703
Zy-Zy	2,808	2,735	2,684
P-Br	1,368	1,401	1,378
Nm-Nm	-0,373	-0,404	-0,317
Constant	-654,999	-673,814	-658,740

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM- Southern Carpathians.

Another important aspect is the ranking of the functions of the variables (items) within the groups shown in Table 46, which through its positive and negative indices shows the score obtained by each item, providing clues on the ranking of the cases.

Table 47. Estimated classification and observed classification for dorsal face, total samples

Group	Percent estimated %	CO p=0,3677	CC p=0,3843	CM p=0,2479
CO	63,82979	60	23	11
CC	70,70707	23	70	6
CM	41,26984	21	16	26
TOTAL	60,93750	104	109	43

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM- Southern Carpathians.

The result of the analysis is shown in Table 47, where the estimated classification matrix, as a percentage of the cases by group, was made in proportion to the number of cases. It can be seen that for the dorsal face in the case of the Eastern Carpathians the estimated classification is 63.82% with 60 cases classified correctly and 33 incorrectly, the Curvature Carpathians with 70.70% with 70 cases classified correctly and 29 incorrectly, and the worst estimate is the Southern Carpathians with 41.26% respectively 26 cases classified correctly and 37 incorrectly.

The estimated percentage for the total experiment is 60.93%.

Discriminant analysis of the dorsal face highlights the following aspects:

Regarding the elements introduced by the model as having the greatest influence in discrimination, for group I the elements Ect-Ect, Op-Br, Da-Da and Nm-Nm were chosen, for group II Ect-Ect, Mo-Mo, P-Br, Fs-Fs, and for the total samples Ect-Ect, Da-Da, Op-Br, Fs-Fs, Mo-Mo, Zy-Zy, P-Br and Nm-Nm.

In terms of the percentage of correct classification, it can be seen that this is highest for age group II with 67.36%, followed by 60.93% for the total group and 59.35% for group I.

The highest estimated classification percentage is obtained by the Curvature Carpathians followed by the Eastern Carpathians and the Southern Carpathians.

4.4.4 Discriminant analysis for ventral, lateral and occipital face for age group I.

For the ventral, lateral and occipital face 13 age group I items were entered into the analysis, the results are shown in Table 48.

Table 48. Discriminant function for age group I, Eastern Carpathians, Curvature Carpathians and Southern Carpathians.

N=150	Wilks' Lambda	Partial Lambda	F-remove (2,140)	p-level	Tolerate.	1-Tolerate. (R-Sqr.)
Con-Con	0,679913	0,884713	9,121679	0,000189	0,671539	0,328461
Mol-P	0,639975	0,939924	4,474126	0,013076	0,325917	0,674083
St-B	0,667324	0,901402	7,656793	0,000699	0,560847	0,439153
P-O	0,658237	0,913847	6,599241	0,001825	0,262999	0,737001
Pm-P	0,644225	0,933723	4,968739	0,008227	0,339724	0,660276
Ot-Ot	0,624461	0,963276	2,668719	0,072868	0,536069	0,463931
M-M	0,623544	0,964691	2,562083	0,080757	0,833848	0,166152
Pm-Pd	0,613508	0,980472	1,394166	0,251462	0,777199	0,222801

Of the 13 variables entered into the analysis, only eight were entered into the model. The Partial Lambda estimator determined that five variables, namely con-con, Mol-P, St-B, P-O and Pm-P, had the power to discriminate, in other words the seven variables contributed significantly, in the order indicated, to the differentiation of the three samples, with the variables Ot-Ot, M-M and Pm-Pd in the model playing an insignificant role. The variables P-B, St-P, Zl-P, Zl-Op and Op-O, were not entered into the model.

Analysing the means of the canonical variables shows that the canonical function 1 differentiates somewhat the group I of the Curvature Carpathians from the Eastern Carpathians and the Southern Carpathians. Canonical function 2 shows a differentiation between the Eastern Carpathians, the Curvature Carpathians and the Southern Carpathians. The graphical representation is shown in Figure 34.

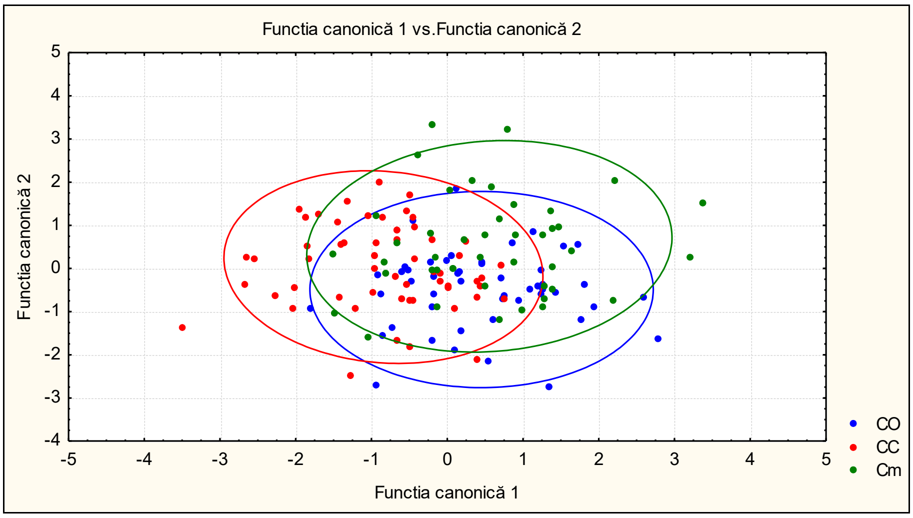

Fig. 34. Canonical score plot for age group I.

Table 50. Classification of functions by sample

Variable(s)	CO	CC	CM
	p= 0,3333	p=0,3733	p=0,2933
Con-Con	1,788	2,030	1,684
Mol-P	0,225	0,103	0,268
St-B	0,217	0,310	0,148
P-O	0,745	0,768	0,848
Pm-P	2,653	2,544	2,473
Ot-Ot	0,337	0,316	0,239
M-M	0,974	1,035	1,052
Pm-Pd	4,935	4,896	4,852
Constant	-857,602	-859,540	-852,207

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM - Southern Carpathians

Another important aspect is the ranking of the functions of the variables (items) within the groups shown in Table 50, which through its positive and negative indices shows the score obtained by each item, providing clues on the ranking of the cases.

Table 51. Estimated classification and observed classification for ventral, lateral and occipital face, age group I.

Group	Percent estimated %	CO p=0,3333	CC p=0,3733	CM p=0,2933
CO	62,00000	31	13	6
CC	73,21429	13	41	2
CM	47,72727	12	11	21
TOTAL	62,00000	56	65	29

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM- Southern Carpathians.

The result of the analysis is shown in Table 51, where the estimated classification matrix, as a percentage of the cases by group, was made in proportion to the number of cases.

It can be seen that the estimated classification of the Eastern Carpathians is 62.00% with 31 cases correctly and 19 incorrectly classified, the Curvature Carpathians 73.21% with 41

cases correctly and 15 incorrectly classified, and the lowest estimate for the Southern Carpathians 47.72% with 21 cases correctly and 23 incorrectly classified.
The estimated percentage for the total experiment is 62.00%.

4.4.5 Discriminant analysis for ventral, lateral and occipital face for age group II.

For the ventral, lateral and occipital face 13 age group I items were entered into the analysis, the results are shown in Table 52.

Table 52. Discriminant function for age group II, Eastern Carpathians, Curvature Carpathians and Southern Carpathians.

N=92	Wilks' Lambda	Partial Lambda	F-remove (2,83)	p-level	Tolerate.	1-Tolerate. (R-Sqr.)
St-B	0,627283	0,863666	6,550974	0,002282	0,728030	0,271970
Zl-P	0,592826	0,913866	3,911477	0,023802	0,618555	0,381445
Mol-P	0,638571	0,848400	7,415589	0,001089	0,381790	0,618210
Zl-Op	0,563158	0,962010	1,638824	0,200429	0,656009	0,343991
P-O	0,564885	0,959068	1,771152	0,176506	0,353086	0,646914
Pm-Pd	0,560819	0,966022	1,459697	0,238208	0,888326	0,111674
Con-Con	0,560295	0,966925	1,419550	0,247632	0,805178	0,194822

Of the 13 variables entered into the analysis only seven of them were entered into the model.The Partial Lambda estimator determined that the discriminating power was found in three variables, namely, St-B, Zl-p and Mol-P, in other words the three variables contributed significantly, in the order indicated, to the differentiation of the three samples, with the variables con-con, P-O and Pm-Pd and Zl-Op in the model playing an insignificant role.The variables P-B, St-P, Pm-P, M-M, Ot-Ot and Op-O, were not entered into the model. Analysing the means of the canonical variables shows that the canonical function 1 differentiates somewhat the Curvature Carpathians group II from the Eastern and Southern Carpathians. Canonical function 2 shows a differentiation between the Southern Carpathians, the Curvature Carpathians and the Eastern Carpathians. The graphical representation is shown in Figure 35.

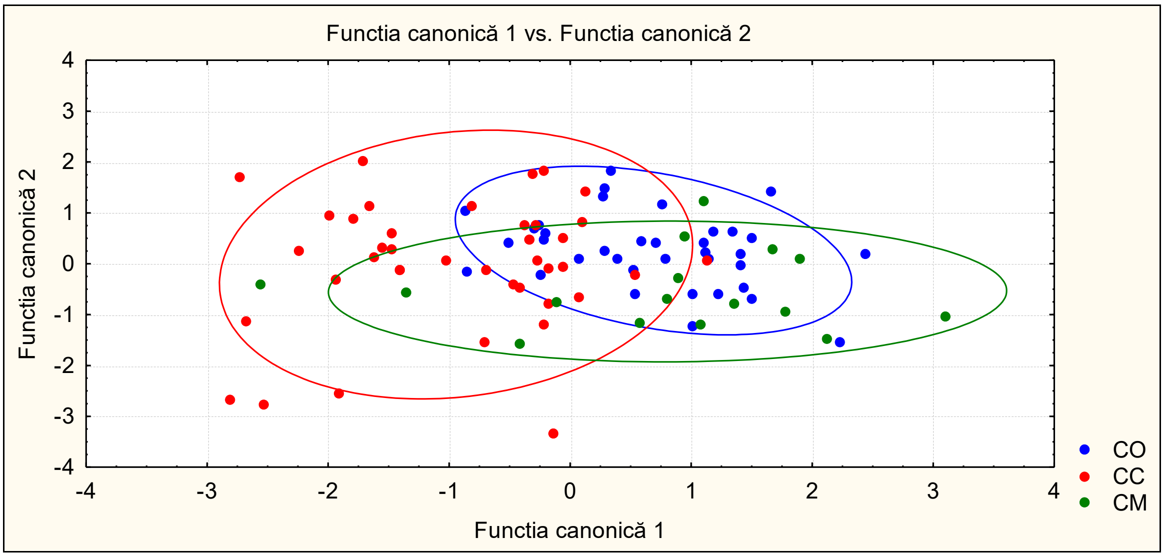

Fig. 35. Canonical score chart for age group I

Table 54. Classification of functions by sample

Variable(s)	CO	CC	CM
	p= 0,3913	p=0,4347	p=0,1739
St-B	0,424	0,572	0,508
Zl-P	1,786	1,877	1,767
Mol-P	-0,234	-0,407	-0,140
Zl-Op	1,733	1,748	1,657
P-O	0,722	0,780	0,709
Pm-Pd	2,779	2,686	2,780
Con-Con	2,535	2,645	2,450
Constant	-868,463	-909,317	-867,206

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM- Southern Carpathians.

Another important aspect is the ranking of the functions of the variables (items) within the groups shown in Table 53, which through its positive and negative indices shows the score obtained by each item, providing clues on the ranking of the cases.

Table 55. Estimated classification and observed classification for ventral, lateral and occipital face, age group II.

Group	Percent estimated %	CO p=0,3913	CC p=0,4347	CM p=0,1739
CO	72,22222	26	8	2
CC	77,50000	8	31	1
CM	18,75000	9	4	3
TOTAL	65,21739	43	43	6

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM- Southern Carpathians.

The result of the analysis is shown in Table 55, where the estimated classification matrix, as a percentage of the cases by group, was made in proportion to the number of cases. It can be seen that the estimated classification of the Eastern Carpathians is 72.22% with 26 cases correctly and 10 incorrectly classified, the Curvature Carpathians with 77.50% with 31 cases correctly and 9 incorrectly classified, and the lowest estimation of the Southern Carpathians with 18.75% respectively 3 cases correctly and 13 incorrectly classified.
The estimated percentage for the total experiment is 65.21%.

4.4.6 Discriminant analysis for ventral, lateral and occipital face per total samples.

For the ventral, lateral and occipital face 13 items were entered into the analysis, the results are shown in Table 56.

Table 56. Discriminant function for total samples, Eastern Carpathians, Curvature Carpathians and Southern Carpathians.

N=242	Wilks' Lambda	Partial Lambda	F-remove (2,232)	p-level	Tolerate.	1-Tolerate. (R-Sqr.)
St-B	0,733544	0,928063	8,99156	0,000173	0,649753	0,350247
Con-Con	0,737188	0,923475	9,61251	0,000098	0,722355	0,277645
Mol-P	0,741262	0,918399	10,30671	0,000051	0,337853	0,662146
Zl-P	0,689651	0,987130	1,51241	0,222542	0,584920	0,415080
Pm-P	0,692931	0,982457	2,07134	0,128341	0,416820	0,583180
M-M	0,690086	0,986507	1,58660	0,206832	0,877750	0,122250
P-O	0,692084	0,983660	1,92697	0,147912	0,277908	0,722092
Ot-Ot	0,691611	0,984332	1,84637	0,160121	0,599621	0,400379

Of the 13 variables entered into the analysis only eight of these were entered into the model. The Partial Lambda estimator determined that the discriminating power was found in three variables, namely, St-B, con-con, and Mol-P, in other words the three variables contributed significantly, in the order indicated, to the differentiation of the three samples, with the variables P-O, Pm-P, M-M, Ot-Ot and Zl-P in the model playing an insignificant role. The variables P-B, St-P, Pm-Pd, Zl-Op and Op-O, were not included in the model.

Analysing the means of the canonical variables shows that the canonical function 1 differentiates somewhat the Curvature Carpathians group from the Eastern and Southern Carpathians. Canonical function 2 shows a differentiation between the Eastern Carpathians, the Curvature Carpathians and the Southern Carpathians. The graphical representation is shown in Figure 36.

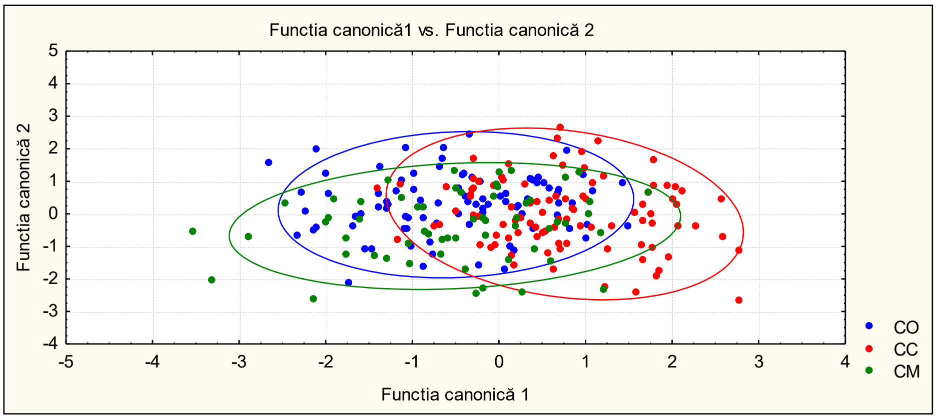

Fig. 36. Canonical score plot by total samples.

Table 58. Classification of functions by sample

Variable(s)	CO	CC	CM
	p= 0,3553	p=0,3966	p=0,2479
St-B	0,340	0,439	0,326
Con-Con	2,316	2,499	2,230
Mol-P	1,199	1,047	1,214
Zl-P	0,820	0,856	0,838
Pm-P	-0,406	-0,427	-0,481
M-M	1,617	1,657	1,663
P-O	0,870	0,898	0,912
Ot-Ot	0,096	0,071	0,034
Constant	-621,611	-641,243	-625,238

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM- Southern Carpathians.

Another important aspect is the ranking of the functions of the variables (items) within the groups shown in Table 58, which through its positive and negative indices shows the score obtained by each item, providing clues on the ranking of the cases.

Table 59. Estimated classification and observed classification for ventral, lateral and occipital face, total samples.

Group	Percent estimated %	CO p=0,3553	CC p=0,3966	CM p=0,2479
CO	58,62069	51	26	10
CC	76,04166	19	73	4
CM	31,66667	24	17	19
TOTAL	58,84774	94	116	33

The result of the analysis is shown in Table 59, where the estimated classification matrix, as a percentage of the cases by group, was made in proportion to the number of cases.

It can be seen that the estimated classification of the Eastern Carpathians is 58.62% with 51 cases correctly classified and 36 incorrectly, the Curvature Carpathians 76.04% with 73 cases correctly classified and 23 incorrectly, and the lowest estimate is the Southern Carpathians with 31.66% respectively 19 cases correctly classified and 41 incorrectly.
The estimated percentage for the total experiment is 65.21%.

Discriminant analysis of the dorsal face highlights the following aspects:
Regarding the elements introduced by the model as having the greatest influence in discrimination, for group I the elements, con-con, Mol-P, St-B, P-O and Pm-P were chosen, for group II, St-B, Zl-P and Mol-P, and for the total samples the elements St-B, con-con and Mol-P.
In terms of the percentage of correct classification, it is observed that it is the highest for age group II with 65.21%, followed by group I with 62.00% and 58.84% for the total sample.

The highest estimated classification percentage is obtained by the Curvature Carpathians followed by the Eastern Carpathians and the Southern Carpathians.

4.4.7. Discriminatory analysis for trophy elements.

For the trophy of the three samples studied, i.e. Eastern Carpathians, Curvature Carpathians and Southern Carpathians, 12 elements were studied.

Table 60. Discriminant function for the Eastern Carpathians, Curvature Carpathians and Southern Carpathians samples.

N=242	Wilks' Lambda	Partial Lambda	F-remove (2,232)	p-level	Tolerate.	1-Tolerate. (R-Sqr.)
NRC	0,863043	0,925042	8,913525	0,000190	0,111442	0,888558
NTR	0,853933	0,934911	7,658293	0,000609	0,108355	0,891645
LRO	0,847509	0,941997	6,773243	0,001398	0,650865	0,349135
CP1	0,829041	0,962981	4,228596	0,015775	0,222868	0,777133
GR	0,824472	0,968318	3,599026	0,028973	0,223334	0,776666
CP2	0,806183	0,990285	1,079175	0,341668	0,177283	0,822717
LRM	0,810660	0,984816	1,695986	0,185807	0,644607	0,355393
RC	0,809768	0,985901	1,573117	0,209722	0,485728	0,514272

Of the 12 variables entered into the analysis only eight of these were entered into the model. The Partial Lambda estimator determined that the discriminating power of eight variables, namely, NRC, NTR, LRO, CP1 and GR in other words the five variables contributed significantly, in the order indicated, to the differentiation of the three samples, with the variables

CP2, LRM and in the model playing an insignificant role. The variables, DCF, Dmax, Dmin and LP, were not entered into the model.

Analysing the means of the canonical variables shows that canonical function 1 differentiates somewhat the Southern Carpathians group from the Eastern Carpathians and the Curvature Carpathians. Canonical function 2 shows a differentiation between the Curvature Carpathians, the Eastern Carpathians and the Southern Carpathians. The graphical representation is shown in Figure 37.

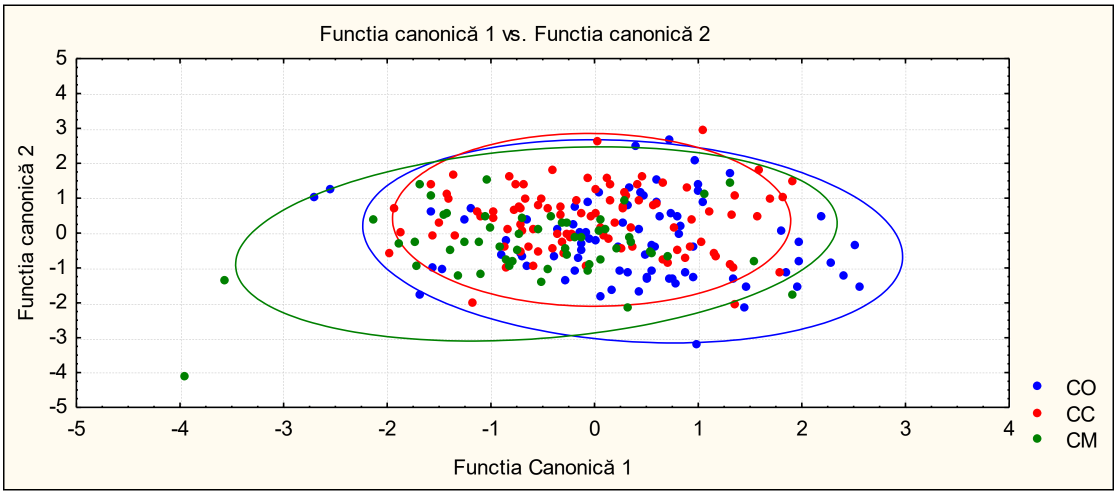

Fig. 37. Canonical score plot per sample.

Table 62. Classification of functions by sample

Variable(s)	CO	CC	CM
	p= 0,3478	p=0,4217	p=0,2304
LRO	0,2584	0,1863	0,143
LRM	0,4893	0,4790	0,537
CP1	3,9312	3,6280	4,229
CP2	3,0408	3,2802	3,002
NRC	-3,7874	-4,4201	-4,761
NTR	5,2378	5,6224	6,090
GR	-9,5001	-9,1149	-9,574
RC	4,1761	4,0529	4,199
Constant	-98,5863	-94,3407	-103,961

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM- Southern Carpathians.

Another important aspect is the ranking of the functions of the variables (items) within the groups shown in Table 52, which through its positive and negative indices shows the score obtained by each item, providing clues on the ranking of the cases.

Table 63. Estimated classification and observed classification for trophy elements

Group	Percent estimated %	CO p=0,3478	CC p=0,4217	CM p=0,2304
CO	**48,14815**	**39**	**34**	**8**
CC	**72,16495**	**18**	**70**	**9**
CM	**32,07547**	**13**	**23**	**17**
TOTAL	**54,54546**	**70**	**127**	**34**

Note: CO-Eastern Carpathians, CC- Curvature Carpathians, CM- Southern Carpathians.

The result of the analysis is shown in Table 63, where the estimated classification matrix, as a percentage of the cases by group, was made in proportion to the number of cases. It can be seen that the estimated classification of the Eastern Carpathians is 48.15% with 39 cases correctly classified and 42 incorrectly classified, the Curvature Carpathians 72.16% with 70 cases correctly classified and 27 incorrectly classified, and the lowest estimate for the Southern Carpathians 32.07% with 17 cases correctly classified and 36 incorrectly classified. The estimated percentage for the total experiment is 54.54%.

Chapter 5. Conclusions. Personal contributions.

5.1. Conclusions

Conclusions for Objective 1.

1. The morphoanatomical study of the skull has been carried out using 28 elements, 15 for the dorsal face and 13 for the ventral and occipital faces, and the analysis of the trophy was approached through the prism of 12 elements also used to calculate the score and evaluation.
2. Eleven cranial indices characterizing the skull by means of elements (anatomical processes of the cranial faces) were defined for two age groups and three samples respectively, Eastern Carpathians, Curvature Carpathians and Southern Carpathians. The indices illustrating the shape and dimensions of the skull have the highest values for the Eastern Carpathians, as well as the indices defining the frontal bones, while a decrease in their values with age was also observed in the Polish samples (Mystowska, 1966). The indices characterising the occipital face have the highest values for the Southern Carpathians, as well as the processes defining the dimensions of the dental palate in relation to the width of the viscerocranium.
3. The statistics (t-Student) revealed the following: the means of the Zy-Zy/P-Br, show a significant difference, manifested at the level of age group I, between the Eastern and Southern Carpathians; the means of the St-P/P-Op index show two distinctly significant differences for age group II, respectively the first between the Eastern and the Curvature Carpathians and the second between the Curvature and the Southern Carpathians; the Br-N/Ect-Ect index means show a single significant difference between the Eastern Carpathians and the Curvature Carpathians in age group II; in the neurocranium, the Eu-Eu/St-B index means show a distinctly significant difference between the Eastern Carpathians and the Curvature Carpathians samples, and a significant difference between the Eastern Carpathians and the Southern Carpathians samples. Significant differences are recorded in the second age group between the Eastern Carpathians and the Curvature Carpathians.
   A final conclusion on the objective addressed is that there are significant and distinctly significant differences between the means of some of the cranial indices subjected to analysis, both within age groups and within samples, namely the Eastern Carpathians, the Curvature Carpathians and the Southern Carpathians.

Conclusions for Objective 2.

1. The analysis of the coefficient of variation for the dorsal face at age group and sample level shows values below 10%, thus proving the homogeneity of the samples extracted from the population.
2. Analysis of variance revealed a significant number of significant, distinctly significant and highly significant differences in some cranial anatomical processes between the Eastern Carpathians, Curvature Carpathians and Southern Carpathians samples.
3. The analysis of the coefficient of variation for ventral, lateral and occipital faces at age group and sample level also shows values below 10% proving the homogeneity of the extracted samples, the analysis of variance also reveals significant, distinctly significant and highly significant differences.

4. The values of the coefficient of variation for certain elements of the trophy exceed the limits allowed for their characterisation, their processing requiring prior homogenisation and normalisation. The analysis of variance applied after homogenisation revealed significant and distinctly significant differences between the elements of the trophy. Among these elements, the total number of branches in the crown, the total number of branches per pole, the length of the eye radius and the maximum opening of the trophy stand out. This suggests that these traits have a strong genetic influence as a result of repeated stocking with genetic material from western deer populations precisely to improve these traits (Bradvarovic, 2017).

Conclusions for Objective 3.

1. The intensity of the links between the trophy elements and the cranial architecture represented by its elements, for the three samples studied, namely the Eastern Carpathians, the Curvature Carpathians and the Southern Carpathians, have been studied using simple and multiple correlation analysis. The expression of this relationship is found in the simple and multiple correlation coefficients.
2. For the Eastern Carpathians age group I, significant correlations between dorsal face elements are low in number. They did, however, highlight the defining links between trophy elements and important structural cranial elements. For age group II, new significant correlations appear, some of them inverse, suggesting the hypothesis that the growth arrest of cranial elements at older ages is inversely related to the continuously developing trophic elements. Positive correlations are also observed between elements of the frontal and orbital regions, which play a direct role in supporting the trophy. Using multiple correlation, where one trophic element was expressed through several cranial elements, 7 multiple regression equations have been generated for age group I, 10 for age group II and 10 for the total sample.
3. For the Curvature Carpathians age group I, the number of significant, distinctly significant and highly significant correlations is significant, showing the numerous links made between cranial elements and trophy elements. For age group II as well as for the total sample, the number is lower. The multiple correlation applied revealed a number of 11 multiple regression equations for age group I, 12 for age group II and 10 for the total sample.
4. For the Southern Carpathians age group I, there are a significant number of significant, distinctly significant and highly significant correlations. Another observation is that trophic elements that are expressed as lengths, i.e. LP, LRO and LRM, do not correlate significantly with any cranial element, except LP which correlates with P-Br. For age group II, it is observed that the number of significant correlations is reduced compared to group I. Multiple correlations revealed a significant number of multiple regression equations, 11 for age group I, 12 for age group II and 10 for the total sample.
5. Between the cranial elements of the ventral, lateral and occipital face (13 elements) and the trophy elements (12 elements), for the Eastern Carpathians, age group I, there is only one significant correlation between the length of the poles and the maximum height of the occipital face (Ot-Ot), the other correlations being insignificant. For age group II, correlations are low, and for the total sample there are a significant number of significant correlations, expressing proportionality relationships between trophy elements and ventral, lateral and occipital face elements. The multiple correlation of the elements of the two age groups and the total sample revealed a significant number

of multiple regression equations performed between trophy elements and cranial face elements: 7 for age group I, 9 for age group II and 9 for the total sample.

6. In the Curvature Carpathians sample, for age group I, with the exception of the Dmax and Dmin elements, all trophic elements correlate significantly, distinctly significantly and highly significantly with the P-B, P-O, St-P, Mol-P and Pm-P cranial elements. There are also correlations between the trophy elements and the cranial elements Zl-P and Ot-Ot. There are no significant correlations between the trophy elements and the cranial elements represented by the processes Pm-Pd, M-M, Zl-Op, Con-Con and Op-O. For age group II and for the total sample, the picture of significant, distinctly significant and highly significant correlations is almost identical. For multiple correlation, there are a significant number of regressions, i.e. 7 for group I, 9 for group II and 8 for the whole sample.
7. For the Southern Carpathians sample, age group I, the DCF, NRC and Dmax elements correlate significantly with the ventral face structural elements P-B, P-O, St-B, Pm-P, and also correlate significantly and distinctly significantly with the lateral and occipital face elements Zl-P, Ot-Ot, respectively. For age group II, the DCF, NRC, Dmax and Dmin elements do not correlate significantly with the cranial elements of the ventral, lateral and occipital faces, except for the NRC and Dmax elements which correlate significantly with Pm-Pd. For length elements, LP correlates with St-P, LRO with Zl-Op, and with occipital face elements respectively Ot-Ot and Con-Con. The total number of branches, NTR, correlates significantly and distinctly with ventral face elements, one lateral face element and one occipital face element. Trophy weight correlates with three ventral face elements, one lateral face element and one occipital face element. In terms of multiple correlation, there are a significant number of regressions, 10 for group I, 9 for group II and 10 for the whole sample.

Conclusions for Objective 4.

To determine the maximum degree of differentiation of the samples studied by means of the component elements, discriminant analysis using the *forward stepwise* method was applied to each cranial face and trophic elements, resulting in the following:

1. For the dorsal face, the elements with the highest weight in the discrimination process are: Ect-Ect, Da-Da, Op-Br, Fs-Fs, Mo-Mo, Zy-Zy, P-Br with a classification percentage 63.82% for the Eastern Carpathians, 70.70% for the Curvature Carpathians and 41.26% for the Southern Carpathians, with a percentage 60.93% for the total experiment.
2. For the ventral, lateral and occipital faces, the cranial elements with the highest weight in the discrimination process are St-B, Con-Con and Mol-P, with a classification percentage of 58.62% for the Eastern Carpathians, 66.04% for the Curvature Carpathians and 31.66% for the Southern Carpathians, with a percentage of 58.84% for the total experiment.
3. For the trophy, the elements with the highest weight in the discrimination process are NRC, NTR, LRO, CP1and GR, with a classification percentage of 48.14% for the Eastern Carpathians, 72.12% for the Curvature Carpathians and 32.07% for the Southern Carpathians, with a percentage of 54.54% for the total experiment.

5.2. Personal contributions

1. Definition of 11 cranial indices characterising the shape and size of the skull as a whole by means of 28 elements (cranial anatomical processes) for the Eastern Carpathians, the Curvature Carpathians and the Southern Carpathians.
2. Comparing cranial indices and determining (using statistical tools) the significance of differences between them in the context of variability.
3. Carrying out a detailed multi-criteria analysis of the dorsal, ventral, lateral and occipital face elements and characterising them in terms of variability for the Eastern Carpathians, the Curvature Carpathians and the Southern Carpathians.
4. Conduct a detailed multi-criteria analysis of trophic elements and characterize them in terms of variability for the Eastern Carpathians, Curvature Carpathians and Southern Carpathians.
5. Establishing significant differences between the Eastern Carpathian, Curvature Carpathian and Southern Carpathian samples of skull and trophy face elements, a feature of variability, using analysis of variance.
6. Characterization of the three samples, respectively, the Eastern Carpathians, the Curvature Carpathians and the Southern Carpathians by age groups, in terms of statistical relationships (correlations) of the cranial face elements and trophy elements by means of simple and multiple correlation coefficients.
7. Generation of a large number of simple and multiple regression equations as a mathematical expression of the links made between cranial elements and trophic elements, their temporal evolution during growth and development.
8. Determination through discriminant analysis of the skull face and trophy elements with the strongest differentiation ability of the studied samples, i.e. Eastern Carpathians, Curvature Carpathians and Southern Carpathians.

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ABSTRACT

Variability, an important characteristic of living systems, expressed at the individual and population level through numerous epistatic effects, generates a number of distinct structural changes under the influence of external factors.

The present study proposes to analyse this variability for three populations of red deer (*Cervus elaphus* L.) in the Romanian Carpathians, namely, the Eastern Carpathians, the Curvature Carpathians and the Southern Carpathians, orographic units with different altitudinal, petrographic and vegetation characteristics. The samples extracted from these populations are confined to hunting grounds, 64 hunting grounds in the Eastern Carpathians with 97 specimens, 47 hunting grounds in the Curvature Carpathians with 105 specimens and 50 hunting grounds in the Southern Carpathians with 72 specimens.

Each specimen was assessed for age, resulting in a stratification of the respective sample, age group I (7-9 years) and age group II (10 years and older).

Sample variability was investigated using 28 elements (cranial anatomical features) and 11 trophy elements, resulting 11 cranial indices being analysed.

As a primary investigation technique, indices of experimental distributions expressed by mean values (arithmetic mean, weighted arithmetic mean), indices of dispersion expressed by variance, standard deviation, standard error of means, coefficient of variation have been used, with significance examination performed using Student, Fisher theoretical distributions.

Dispersion analysis has been used to highlight differences between the samples analysed, and the statistical relationships established were investigated using correlation analysis, then expressed by means of correlation coefficients and simple and multiple regression equations.

The interaction of ecological factors (biotic and abiotic) on the population often results in simultaneous causal relationships with pronounced feedback and expressed synergistically. These issues were investigated using multivariate analysis, discriminant analysis and canonical correlation analysis techniques.

Comparative analysis of cranial and trophy elements in these areas, through the perspective of variability, promotes the hypothesis of important variation that may generate ecotypes within Romanian deer populations. An in-depth analysis, by extending the studies, spatially, genetically, anatomically (increasing the number of anatomical features investigated) but also the analysis of smaller age classes will be able to create an overall picture of the structure of deer populations providing researchers and hunters with important clues on the sources of variation, changes and development over time of valuable elements of deer trophies, necessary for scientific hunting practices.