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MORPHOLOGICAL VARIABILITY OF THE CROATIAN WILD BOAR POPULATION

MORFOLOŠKA VARIJABILNOST POPULACIJE DIVLJE SVINJE U HRVATSKOJ

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ABSTRACT: Between 2007 and 2009, a total of 181 individual wild boar were scored using nineteen morphological measurements from three geographical regions to describe morphological variety of the population throughout Croatia. In some regions we found phenotypical variability of the wild boar population based on hybridization The results of ANOVA show that some variables were significantly different (body weight, tail length, trunk length) but some of them were not homogenous for all age classes (circumference of shin, the most caudal point of scapula, circumference at chest) and were unable to highlight differences among the areas. The redundancy analysis (RDA) showed a connection of sampling sites with some morphological trait. Results of cluster analysis using TREE procedure indicate separation on the two subpopulations and suggesting the existence of morphological differences. Overall the results confirmed that different morphotypes of wild boar are detectable in some different areas of Croatia, and in some counties the wild boar population has been hybridized with domestic pigs, which result in phenotypical variability where the wild characteristics predominate. These results confirmed the need for population genetic studies to identify the different subpopulations of wild boar presently found in Croatia

Key words: wild boar, Croatia, morphological variability

INTRODUCTION – Uvod

The Eurasian wild boar (*Sus scrofa* L.) is one of the most widely distributed terrestrial mammals, a native game of Croatia and economically very important species which significantly increased in numbers during the last decades. Geographically, Croatia has a specific position in Europe where in a narrow zone of 150 km three different types of geographical elements are present, continental-Pannonian basin, continental-Dinaric mountains and Mediterranean area. Therefore these regions are suitable and have high potential for the study of zoogeographic population characteristics and dynamics. One of the biggest problems of wild boar population in Croatia is hybridization with domestic pigs which most often occurred after the war in the 1990's (Šprem 2009). The consequence of this unwanted hybridization can be seen in a completely different animal phenotype. Morphological and quantitative data concerning wild animals is still scarce and more information is needed. It is one of the most important phenotypic characteristics of an animal, influencing fitness, life history and population ecology (Tymchuk et al. 2006). These data will be interesting especially in species with some potential for intensive exploration such as a biological model for wild boar (Câmara Filho et al. 2003), and they provide information on the growth and development of wild

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boar, as well as on quality of the habitat. Gross external morphological parameters have been the most common area used by researchers to attempt to define identifying characteristics. This is at least in part due to the relative ease of data collection using these structures compared to features requiring the use of more complex laboratory methods. Morphological criteria have included a variety of structures and parameters including external body measurements, and coloration. Morphology is an area of research where the shape and size of a morphological individual or characteristic is described with quantitative analysis, and because of very low heritability (h^2), morphology characteristics are very dependent on external conditions (Oxnard 1978). Multivariate statistical methods were applied to classify morphology differences and using these methods it was possible to evaluate the most important characteristics separating the subpopulations defined by wild boar. Relatively little data are available on the relationships among morphological parameters of wild boar. This data mostly dealing with growing patterns of different parameters were analyzed and some results were presented on the correlations and allometry of these characteristics. Better management of wild boar populations requires more morphological data. Therefore, the aim of this study was 1) to determine morphological differences among wild boars populations located in three Croatian geographical regions using morphological measurement; and 2) determine the existence of hybridization.

MATERIAL AND METHODS – Material i metode)

From October 2007 to January 2009, sampling of wild boar populations was conducted in three Croatian geographical regions, East (Đakovo, Baranja, Bilogora) Central (Lpolje, Banija) and West (Plominska, Oprtalj, Grožnjan, SjVeleb, VelKapel, LicSredo) (Fig 1), where we covered three characteristic climate areas under Köppen's climatic classification. The Eastern and Central region enjoys the Cfb climate, but on the other hand the Western region is under the influence of the Cfa and Df climate (Šegota & Filipčić 2003).

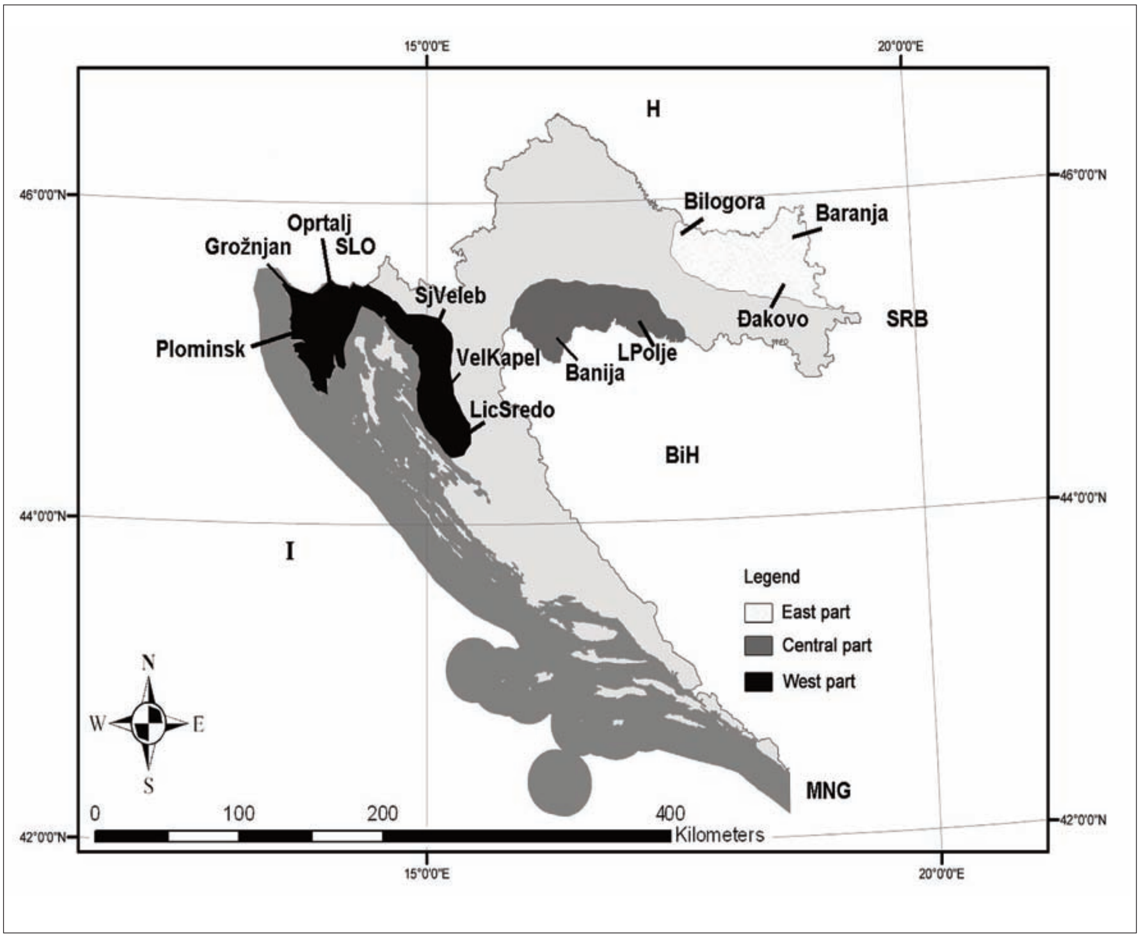

Figure 1 Three different geographical regions and sampling sites in the study
Slika 1. Tri različite geografske regije i lokacije uzorkovanja u istraživanju

Generally, a climatic, agricultural, and forestry vertical gradient characterizes the Croatian territory, with a flat Eastern region of the Pannonian Valley strongly influenced by the Drava and Danube Rivers. This terrain also includes large agricultural fields and predominantly oak and beech forests (N 45°43'28,2" EO 18°50'24,7"). A Central hilly region with small agriculture fields and mainly beech and chestnut forests (N 45°15'23,4" EO 16°15'26,7"), the Western region includes big mountains (N 44°46'28,4" EO 15°01'53,9") and the typical Mediterranean region of the Adriatic Sea with small agriculture fields (N 45°12'59,4" EO 14°13'21,5"). These locations were used because data of genetic analysis showed similarity among same sampling sites (Šprem 2009). All animals presented phenotypic characteristics of the species. The hunted wild boars were sexed, weighed and measured. All the animals included in the study were hunted during the legal drive hunting season. The age of the animals were estimated using patterns of tooth eruption and replacement (Boitani & Mattei 1992). The animals were classified into three age classes (Pedone et al. 1991): juvenile (less than one year of age), yearling (between 1 and 2 years of age), and adult (older than two years of age). Wild boars were measured from the left side, and measurements were carried out using a Lydthin stick, tape measure and scale. A total of 181 individuals (97 males and 84 females) from six month to seven years of age were scored for the nineteen morphological measurements: height at withers HW; height at sacrum HS; height of back HB; the most caudal point of scapula mCPS; height at hip HH; depth of chest DC; circumference at chest CC; head length HL; ear length EL; ear width EW; tail length TaL; trunk length TrL; bristles length (at wiethers) BL; circumference of shin (tibia) CS; circumference of testis (left) CTL; circumference of testis (right) CTR; length of trunk with head TrHL; body weight BW; color of bristles CB. Based on the age class data where preliminary analyzed with ANOVA (using GLM procedure) for fixed effect of region, gender and their interaction on each applicably measurement. For measurements of CTL and CTR ANOVA was tested for effects of region as fixed factor only on male part of dataset. Significant effects of region were additionally tested using Tukey HSD test. After determining variability with ANOVA, data where merged and cluster analysis (using CLUSTER procedure by Ward method and Euclidian distances) where preformed for determining location groupings on averages of 14 relative morphological measurements. Results of cluster analysis are shown graphical (using TREE procedure). Canonical discriminant analysis (using DISCRIM procedure) where preformed on region and relative morphological measurements as given classification. ANOVA, cluster analysis and canonical discriminate analysis where preformed in SAS package (SAS Institute, 2007). For distinguishing which morphological measurement allowed different morphotypes constrained redundancy analysis (RDA) by the CANOCO program (Braak & Smilauer 2002) which is used for sound statistical modeling of ecological data. The Monte Carlo unrestricted permutation test was performed to determine the significance of the regression. For RDA analysis, the measurement was expressed in percentage of height at withers. This is a very important parameter in morphological studies of animals (Melaku 2003). Species data (response variables) represents morphological measurements and environmental data (explanatory variables) represents dummy variables.

RESULTS – Rezultati

The average age of studied animals was under 24 months old, which indicated a relatively young population. The sex ratio is slightly unbalanced in favor of males, a similar unbalanced fetal sex ratio was also found by (Massei et al. 1996). However, the sex ratio did not attribute to the age or, weight. Morphological data support the hypothesis that the wild boar populations in some regions have hybridized with domestic pigs. Some individuals in the data set displayed white hair on the feet, stomach, tarsus and carpus; large and fast growth; great intrapopulation morphological variability; and, great accumulation of subcutaneous fat. Mean values with standard deviation of the seventeen analyzed morphological measurements under three different geographical zones and three different age groups of the animals are presented in Table 1. Statistical differences were observed between age classes, results put in evidence that some variables were significantly different (BW, TaL, TrL), but some of them were not homogenous for all age classes (CS, mCPS, CC) and were unable to highlight differences among the regions. Additional effects of gender on differences between regions were recorded on traits (BW, EL, TaL, TrL) only in sub-adult age class. The correlation analysis shows a significant link between measurements and age classes. Results of RDA analysis throughout sampling sites based on 16 morphological traits are showed in Fig 2. There is a strong correlation between CB in Central and West populations with the CS and TrL. West and East populations are connected with HL and BL, but Central and East populations are strongly correlated with HH, EW and mCPS (Fig 2a). Analysis of young, adolescents

Table 1 Mean ±SD of morphological measurements of wild boar from 3 regions in Croatia and F-values with probability for effect of region, gender and region-gender interaction on morphometric traits

Tablica 1. Srednja vrijednost ±SD morfoloških mjerenja divljih svinja iz 3 regije u Hrvatskoj i F-vrijednosti s vjerojatnošću utjecaja regije, spola i interakcije regija-spol na vrijednost morfološke osobina

Morphological measurement *Morfološke mjere*	East/*Istok*	Central/*Središnji*	West/*Zapad*	Region/*Regija* F-value (P>F)	Gender/*Spol* F-value (P>F)	Region*Gender *Regija*Spol* F-value (P>F)
Young/*Mladi*						
Number/*Broj*	47	32	15			
Body weight/*Tjelesna težina*	31.032±7.955 A	37.325±10.826 B	39.1±6.574 B	7.06 (0.0014)	0.32 (0.5742)	2.13 (0.1249)
Height at withers/*Visina u grebenu*	61.2±6.883 A	64.656±7.196 AB	67.54±7.271 B	5.25 (0.007)	0.28 (0.5967)	0.29 (0.747)
Height of back/*Visina leđa*	60.534±6.598	63.631±8.576	65.473±7.899	3.2 (0.05)	1.42 (0.23)	0.26 (0.773)
Height at sacrum/*Visina križa*	59.63±6.626	61.609±8.898	62.933±6.781	1.32 (0.2682)	0.41 (0.526)	0.19 (0.83)
The most caudal point of scapula/ *Visina prednje noge od vrha plećke do tla*	57.053±6.435	58.541±6.924	59.6±9.216			
Height at hip/*Visina kuka*	57.272±6.447	56.847±7.478	56.8±8.809	0.04 (0.9647)	0.45 (0.5029)	0.22 (0.8068)
Depth of chest/*Dubina prsiju*	33.134±3.916 A	33.856±6.608 A	38.013±2.995 B	5.04 (0.0085)	0.08 (0.7771)	1.19 (0.3105)
Circumference at chest/*Opseg prsiju*	73.726±7.562	79.356±10.918	81.42±5.841			
Head length/*Dužina glave*	51.461±3.468	50.169±6.555	53.236±7.422	2.12 (0.1257)	5.32 (0.0234)	3.05 (0.05)
Ear length/*Dužina uške*	11.066±1.492	11.288±1.732	11.48±1.629	0.47 (0.6259)	0.12 (0.7319)	2.18 (0.1196)
Ear width/*Širina uške*	10.191±1.253	9.838±1.2	9.427±1.125	2.23 (0.1135)	0.47 (0.4943)	0.11 (0.8945)
Tail length/*Dužina repa*	17.326±3.784 A	19.191±3.609 AB	16.247±3.352 B	4.27 (0.0169)	0.06 (0.7994)	0.82 (0.4419)
Trunk length/*Dužina trupa*	68.287±7.83 A	75.434±7.63 B	80.94±4.791 C	19.48 (<0.0001)	0.31 (0.5763)	0.51 (0.604)
Bristles length (at wiethers)/ *Dužina čekinja na grebenu*	10.128±1.65 A	11.141±2.329 AB	12.38±1.35 B	9.12 (0.0003)	0.22 (0.6373)	3.08 (0.05)
Circumference of shin (tibia)/*Opseg cjevanice*	11.496±1.103	13.122±1.469	13.32±1.348			
Circumference of testis (left)/ *Opseg lijevog testisa*	6.06±1.74	7.30±5.64	5.8±0.64	1.45 (0.2543)		
Circumference of testis (right)/ *Opseg desnog testisa*	6.23±1.91	7.43±5.71	8.22±0.98	1.84 (0.1802)		
Sub-adults/ *Srednjedobni jednogodišnjaci*						
Number/*Broj*	10	12	10			
Body weight/*Tjelesna težina*	75.9±5.77 A	86.13±10.613 B	66.625±8.878 C	15.36 (<0.0001)	0.88 (0.3568)	5.25 (0.0095)
Height at withers/*Visina u grebenu*	79.358±3.628	77.49±3.899	74.317±6.577	2.83 (0.0761)	0.28 (0.5979)	1.32 (0.2823)
Height of back/*Visina leđa*	78.017±4.317 A	74.8±3.747 AB	71.075±4.874 B	6.9 (0.0037)	0.15 (0.6974)	1.34 (0.2784)
Height at sacrum/*Visina križa*	74.383±4.873	71.97±3.549	69.65±5.364	2.62 (0.0903)	0.01 (0.9086)	0.22 (0.8059)
The most caudal point of scapula/ *Visina prednje noge od vrha plećke do tla*	72.533±5.852	67.88±6.238	64.725±5.96			
Height at hip/*Visina kuka*	75.3±4.416 A	65.45±4.351 B	61.942±6.043 B	22.23 (<0.0001)	1.87 (0.1829)	0.37 (0.6925)
Depth of chest/*Dubina prsiju*	46.417±1.676 A	42.52±4.879 AB	41.717±6.446 B	4.08 (0.0279)	0.59 (0.4496)	3.16 (0.0577)

Morphological measurement *Morfološke mjere*	East/*Istok*	Central/*Središnji*	West/*Zapad*	Region/*Regija* F-value (P>F)	Gender/*Spol* F-value (P>F)	Region*Gender *Regija*Spol* F-value (P>F)
Circumference at chest/*Opseg prsiju*	106.483±6.989	106.77±8.133	91.2±11.193			
Head length/*Dužina glave*	52.22±5.209	49.89±3.525	50.173±3.522	1.14 (0.333)	0.17 (0.6858)	0.67 (0.5193)
Ear length/*Dužina uške*	12.2±1.134 A	14.72±2.68 B	12.367±0.657 A	11.9 (0.0003)	4.26 (0.0485)	20.94 (<0.0001)
Ear width/*Širina uške*	11.833±1.096 A	11.77±1.523 A	9.85±0.703 B	12.09 (0.0002)	1.18 (0.2872)	0.73 (0.4907)
Tail length/*Dužina repa*	22.492±6.106 A	23.95±3.287 A	17.55±1.973 B	10.44 (0.0004)	0.3 (0.5862)	8.41 (0.0014)
Trunk length/*Dužina trupa*	91.167±4.747	92.57±7.6	92.025±7.079	0.08 (0.9224)	2.76 (0.1076)	7.73 (0.0021)
Bristles length (at wiethers)/ *Dužina čekinja na grebenu*	10.692±1.151	11.77±0.7803	10.467±2.955	1.27 (0.2956)	1.12 (0.2995)	0.24 (0.7908)
Circumference of shin (tibia)/*Opseg cjevanice*	10.692±1.151	11.77±0.78	10.467±2.955			
Circumference of testis (left)/ *Opseg lijevog testisa*	6.06±1.74	7.30±5.64	5 8.0±0.64	1.45 (0.2543)		
Circumference of testis (right)/ *Opseg desnog testisa*	6.23±1.91	7.43±5.71	8.22±0.98	1.84 (0.1802)		
Adults/*Odrasli*						
Number/*Broj*	14	20	21			
Body weight/*Tjelesna težina*	89.607±8.242 A	111.445±13.685 B	110.524±18.612 B	12.49 (<0.0001)	0.08 (0.7768)	1.56 (0.2194)
Height at withers/*Visina u grebenu*	84.593±3.689 A	86.155±5.133 A	90.986±4.406 B	9.24 (0.0004)	0.10 (0.7521)	0.88 (0.4205)
Height of back/*Visina leđa*	81.586±4.757 A	84.27±9.463 AB	87.41±4.45 B	3.55 (0.0365)	0.16 (0.6877)	0.63 (0.5346)
Height at sacrum/*Visina križa*	78.907±5.44 A	80.425±5.337 A	84.562±6.496 B	6.05 (0.0045)	1.19 (0.2806)	2.32 (0.1093)
The most caudal point of scapula/ *Visina prednje noge od vrha plećke do tla*	78.45±5.403	78.655±5.564	79.21±6.546			
Height at hip/*Visina kuka*	78.007±4.296	75.585±6.402	76.257±6.449	0.4 (0.6712)	0.5 (0.4813)	2.29 (0.1117)
Depth of chest/*Dubina prsiju*	49.807±2.724	48.445±9.481	50.2±4.341	0.72 (0.4918)	0.69 (0.4099)	1.21 (0.3068)
Circumference at chest/*Opseg prsiju*	112.086±6.715	118.145±10.787	115.648±14.287			
Head length/*Dužina glave*	51.714±3.799	53.05±4.686	51.774±3.156	0.83 (0.4404)	0.15 (0.6956)	1.96 (0.152)
Ear length/*Dužina uške*	13.407±3.14	14.025±2.081	14.714±2.11	0.56 (0.5758)	0 (0.99)	0.46 (0.6316)
Ear width/*Širina uške*	12.143±2.982 A	13.3±2.056 A	10.081±0.743 B	10.68 (0.0001)	2.18 (0.1463)	0.35 (0.7092)
Tail length/*Dužina repa*	23.457±4.085 A	26.19±4.635 AB	21.652±4.206 B	6.15 (0.0041)	3.33 (0.0739)	1.02 (0.3693)
Trunk length/*Dužina trupa*	100.457±8.814 A	102.105±7.58 AB	109.676±13.645 B	3.78 (0.0298)	1.08 (0.304)	1.43 (0.2484)
Bristles length (at wiethers)/ *Dužina čekinja na grebenu*	11.014±0.687 A	10.67±2.253 A	14.495±2.082 B	18.54 (<0.0001)	0.63 (0.432)	0.08 (0.9211)
Circumference of shin (tibia)/*Opseg cjevanice*	14.821±1.126	16.205±1.15	17.833±2.455			
Circumference of testis (left)/ *Opseg lijevog testisa*	16.27±3.36	14.22±5.38	16.97±5.24	0.51 (0.6076)		
Circumference of testis (right)/ *Opseg desnog testisa*	16.52±3.78	14.84±5.60	16.90 ±5.12	0.09 (0.9139)		

Regions with same letter are not significantly different – *Regije sa istim slovom nisu značajno različite*

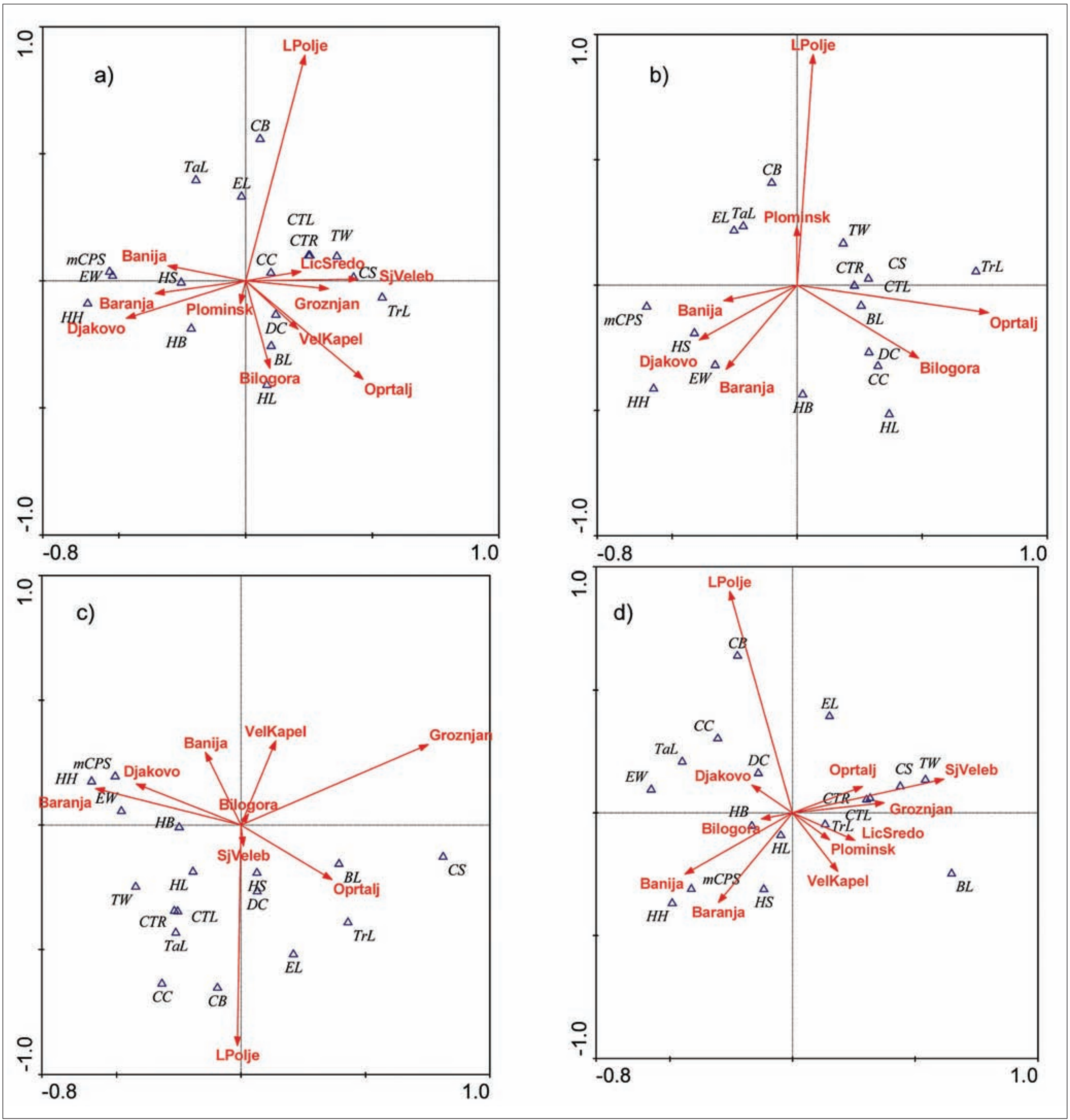

Figure 2 RDA ordination of 11 sampling sites and 16 morphological traits a) all age classes, b) juvenile c) yearling d) adults

Slika 2. RDA koordinate 11 lokacija i 16 morfoloških svojstava a) sve dobne skupine, b) mladi c) jednogodišnjaci d) odrasli

and adults showed similar results at the most locations (Fig 2b, 2c, 2d). Results of cluster analysis using TREE procedure indicate separation on the two subpopulations and suggesting the existence of morphological differences (Fig 3). The first canonical variable accounts for 84.8, 76.5 and 84.2 percent of the total variance for the three ages classes respectively, but is unevenly correlated with the original variables. At first and second canonical variables for the young shows the highest correlation with CS, for sub-adults HH and for adults EW, TL and CC. The discriminant analysis results in the correct classification of the data in the groups shows that Central and East populations are correctly classified and a higher percentage of misclassification can be observed for West population. This result is not easily explainable but the effect of hybridization can be supposed.

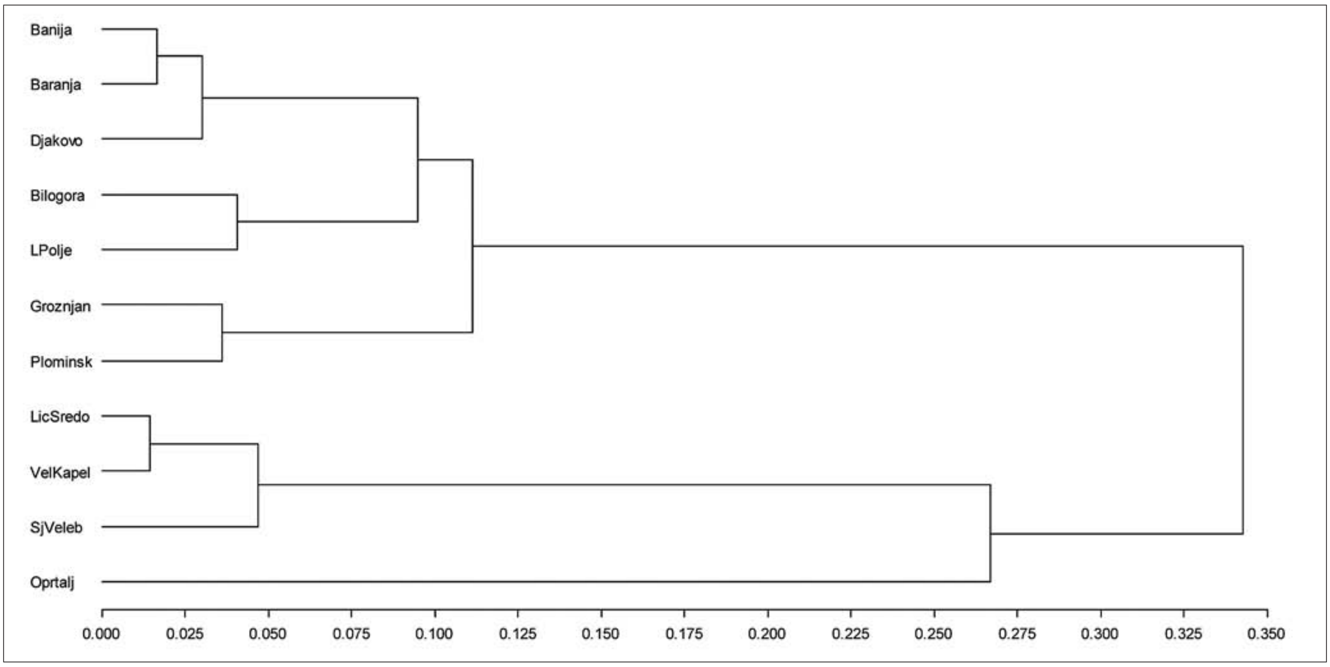

Figure 3 Results of cluster analysis (using TREE procedure)
Slika 3. Rezultat klaster analize (koristeći TREE postupak)

DISCUSSION – Diskusija

Population structure is similar to the cited in studies in Europe, America and Oceania (Herrero & Fernandez de Luco 2003) approximately 70% of individuals were under 24 months old and 6 animals were over 72 months. Morphology data in adult animals can enable one to determine if a specimen in question resembles a pure wild boar or a hybridized animal with domestic pigs, but data presented in this study supported the hypothesis that the wild boar populations have hybridized with domestic pigs. In some regions of Croatia we found phenotypical variability of the wild boar population based on hybridization, but results suggested that the wild characters predominate. Results for some morphological measurement were different than in others studies (Martinoli et al. 1997; Herrero & Fernandez de Luco 2003; Mayer & Lehr Brisbin 2006). For example, TaL and HW were smaller, but EL was the same compared to data presented by Mayer & Lehr Brisbin (2006). The data for TrHL were smaller than was shown by Martinoli et al. (1997). Data from this study revealed that the CC, HL and BW was much higher than from Herrero & Fernandez de Luco (2003). Some of these morphological measurements supported the hypothesis that the wild boar population has hybridized with domestic pig, and the same hypothesis was given in similar studies (Martinoli et al. 1997; Herrero & Fernandez de Luco 2003). In generally standard morphological analyzes did not show clear area of separation in any morphological trait, but on the other hand, RDA analysis showed the connection of sampling sites with some morphological trait. The results of cluster analysis using TREE procedure show that East and Central populations are morphologically very close and belong to one subpopulation, but the West population belongs to another subpopulation. This argument can explain on the basis of different habitat and climate conditions. Western population is under the influence of Mediterranean climate and mountain region constitute a natural barrier between other populations. In some respects this result also confirm hypothesis of the existence of two European subpopulations, western and central populations (Larson et al. 2005). Eigen values were performed and we can be confirmed that body shape analysis using multivariate statistical methods may be useful in the evaluation of conformation and other applications. When all parameters are analyzed, it can be concluded that wild boar from Croatia present a certain degree of variability. These results confirmed that different morphotypes of wild boar are detectable in some different regions of Croatia. These morphotypes are differentiated on the basis of height and length measurements and can be relevant only for older animals. Presently the subpopulation is the accepted way of giving formal recognition to these differences, the origin of which may have been an adaptation to different geographical situations. The average data values presented here are slightly higher than those estimated for other European wild boar populations (Pedone et al. 1991; Ernhaft & Csányi 1995; Amici et al. 2010). However, it should be noted that a large number of the studies reported by various authors from other countries (Randi et al. 1987; Apollonio et al.

1988; Genov et al. 1995; Tinelli et al. 1999), refer to variables not directly comparable with those presented in this study. On the basis of morphological characteristics, the western Croatian wild boar population fits the description of the Italian wild boar (Amici et al. 2010). Because of the large geographic range occupied by wild boar we can concluded that the population is reflected in the great morphological and size variability that characterizes this species. These results confirm and will be the basis of further characterization, and genetic studies required to identify the wild boar subpopulation presently populating Croatia.

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SAŽETAK: Između 2007. i 2009. godine, ukupno 181 jedinki divljih svinja, koristeći devetnaest morfoloških mjera sa tri geografske regije, korišteno je za opis morfološke raznolikosti populacije diljem Hrvatske. U nekim regijama pronašli smo fenotipsku varijabilnost populacije divljih svinja temeljenu na hibridizaciji. Rezultati ANOVA-e pokazuju da su neke varijable bile značajno različite (masa tijela, dužina repa, dužina rila), ali neke od njih nisu homogene za sve dobne skupine (opseg cjevanice, visina prednje noge od vrha plećke do tla, opseg prstiju). Multivarijatna statistička metoda (RDA) pokazala je povezanost lokaliteta s nekim morfološkim osobinama. Rezultati klaster analize pomoću TREE postupka ukazuje na razdvajanje dviju podpopulacija i sugerira postojanje morfoloških razlika. Ukupni rezultati potvrđuju da su različiti morfotipovi divljih svinja detektirani u različitim područjima Hrvatske, a u nekim regijama populacija divljih svinja je hibridizirala s domaćim svinjama, što ima za posljedicu fenotipsku varijabilnost gdje ipak karakteristike divljih svinja prevladavaju. Ovi rezultati potvrđuju potrebu za populacijsko genetskim istraživanja kako bi identificirali različite podpopulacije divlje svinje koje trenutno obitavaju u Hrvatskoj.

Ključne riječi: divlja svinja, Hrvatska, morfološka varijabilnost