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INTERRELATIONS BETWEEN MANDIBULAR PARAMETERS, AGE AND CARCASS IN FEMALE FALLOW DEER (*DAMA DAMA*)

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The study material included 152 mandibles of female fallow deer aged 3 to 12. Each mandible was characterized by 15 measurements. Based on the Principal Components Analysis it was concluded that the size and dimensional constitution of the mandible change with age. The following parameters are subjected to most significant changes: total length, middle height of the ramus. Additionally, the method indicated that there is a moderate interdependency between the mandibular parameters and an eviscerated carcass mass. Pearson's correlation coefficient allowed for determining moderate correlations between the carcass mass, mandible total length, breadth of the third molar and middle height of the ramus.

Key words: Cervidae, age, eviscerated carcass weight, bone.

INTRODUCTION

Determination of population parameters to describe its structures and quality is a fundamental problem in scientific studies and hunting practice. Age structure is one of the key parameters. Evaluation of tooth wear and development is commonly used for determining the age of an animal. In the first two years of life, until the end of odontogenesis in fallow deer, the age can be determined in months based on the known eruption order of particular teeth (Haber *et al*. 1980, Lochman 1987). In older animals, the age is determined on the basis of consumption of teeth. This method is biased because of errors resulting from e.g. differences in diet, which results in different level of teeth usage, and also by subjectivity of the person who evaluates the teeth. Eidmann and Rieck (1934) or Mitchell (1963) laboratory methods are also available. However, their use requires specialist scientific equipment. This is why attempts to find a technically easy method allowing for a precise determination of the age of animals on the basis of absolute measurements are still being made. Mandible is an interesting study material because in the economic sense it is of no value. The eviscerated carcass mass is a commonly accepted indicator of quality. Constitution, age, eviscerated carcass mass and mandibular parameters allow for a broad analysis and search for new parameters describing the population. In this study, we attempt to show the correlations between the above factors.

MATERIAL AND METHODS

The study included 152 female fallow deer obtained in the Game Management Centre of Department of Game Management and Forest Protection, Poznań University of Life Sciences in Poland in the course of seven years. The age of the examined animals was estimated based on the standard method of tooth wear evaluation and it was between 3 and 12 years. Younger animals were not included in the analysis as they had not developed a full set of molars. Females in the third year of their life were classified as group I, four to seven years old females as group II and eight years old and older as group III.

For each female, the eviscerated carcass mass was registered and mandible obtained. Then 15 osteometric measurements were performed according to standard von den DRIESCH (1976) method (Fig. 1):

1. Total length
2. Length of the ramus
3. Length of the corpus
4. Length without diastema and incisors

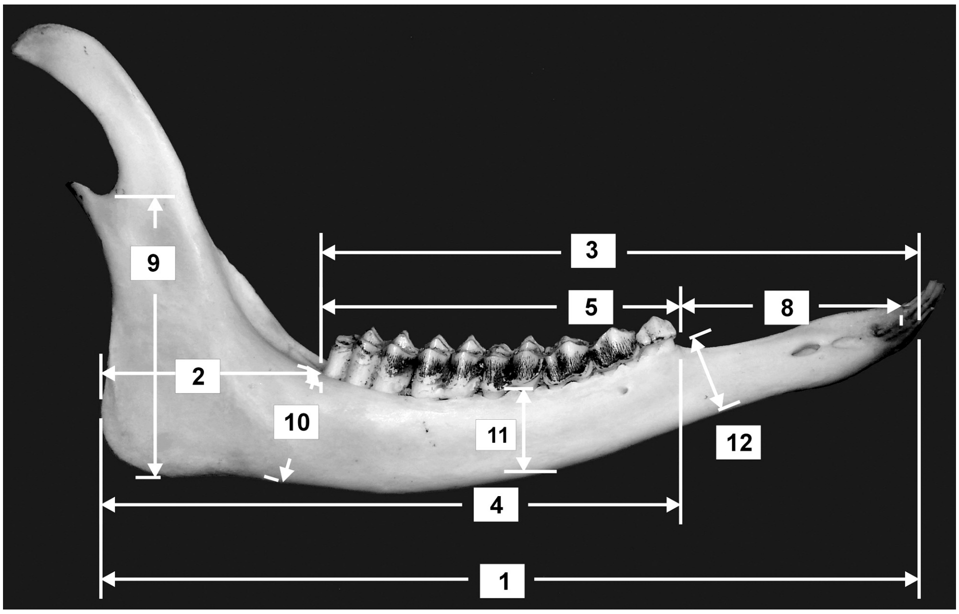

Fig. 1. The selected parameters of fallow deer mandible measurements (the number of measurement is respectively to the number in the text): 1 = total length, 2 = length of the ramus, 3 = length of the corpus, 4 = length without diastema and incisors, 5 = length of the cheektooth row, 8 = length of the diastema, 9 = middle height of the ramus, 10 = height of the corpus behind the third molar, 11 = height of the corpus in front of the first molar, 12 = height of the corpus in front of the first premolar.

5. Length of the cheektooth row
6. Length of the third molar
7. Breadth of the third molar
8. Length of the diastema
9. Middle height of the ramus
10. Height of the corpus behind the third molar
11. Height of the corpus in front of the first molar
12. Height of the corpus in front of the first premolar
13. Thickness of the corpus in front of the first molar
14. Breadth of the condyloid process
15. Thickness of the condyloid process

Principal Components Analysis with a varimax rotation, which belongs to multivariate analyses of data mining methods, was used in the study (Morrison 1990). This method was used to reduce the panel of original variables, which in this case are mandibular metric parameters. As a result of this reduction, new variables were detected, which are hereinafter referred to as components. They allowed for evaluation of metric variability of the examined mandibles and their division into naturally occurring groups. Moreover, the principal components revealed interrelations between the examined parameters of the mandible. The second stage of the study involved Pearson's correlation analysis. Statistical analysis was performed with the Statistica 10.0 software.

RESULTS AND DISCUSSION

Principal Components Analysis and age classes

In the first stage of the study we used the Principal Components Analysis, which allows for an assessment of morphometric differences of the mandibles of the three age classes. Based on the eigenvalue parameter, from among 15 osteometric parameters the number of new principal components was limited to four. These components were chosen because each eigenvalue is greater than 1.0. They jointly explain 57% of the variability conditioned by all the parameters. The first component (PC1) describes 27.8%, whereas the second component (PC2) 14.3 % of the total variability. Both components plotted on a two-dimensional graph showed a variation of mandibles under study (Fig. 2).

The grouping variable, which is denoted on the plot in our study, was the class of age (I–III). It turns out that specimens of the class I have mandibles visibly different than deer of the class III. Specimens of the class II represent an intermediate group, which connects the plot of the other two classes. It can be assumed that the mandibular parameters change with age. As to illustrate the relationship between the measurements and the principal components we used the strategy of varimax rotation (Table 1). On this basis, PC 1 is strongly associated with only two metric features of the mandible. There are features characterizing the total length of the mandibular corpus as well as the middle

Table 1. Component loading matrix after varimax rotation. Component loadings in bold express a strong relation of a given component with the primary trait.

No.	Metric feature	PC 1	PC 2
1	Total length	**0.90**	-0.05
2	Length of the ramus	-0.03	0.04
3	Length of the corpus	0.36	**-0.76**
4	Length without diastema and incisors	0.44	0.04
5	Length of the cheektooth row	-0.15	**-0.91**
6	Length of the third molar	0.42	-0.24
7	Breadth of the third molar	0.58	0.47
8	Length of the diastema	0.58	0.31
9	Middle height of the ramus	**0.79**	-0.17
10	Height of the corpus behind the third molar	0.10	-0.16
11	Height of the corpus in front of the first molar	0.26	0.09
12	Height of the corpus in front of the first premolar	0.04	–0.21
13	Thickness of the corpus in front of the first molar	0.48	0.08
14	Breadth of the condyloid process	0.53	0.18
15	Thickness of the condyloid process	0.18	0.09

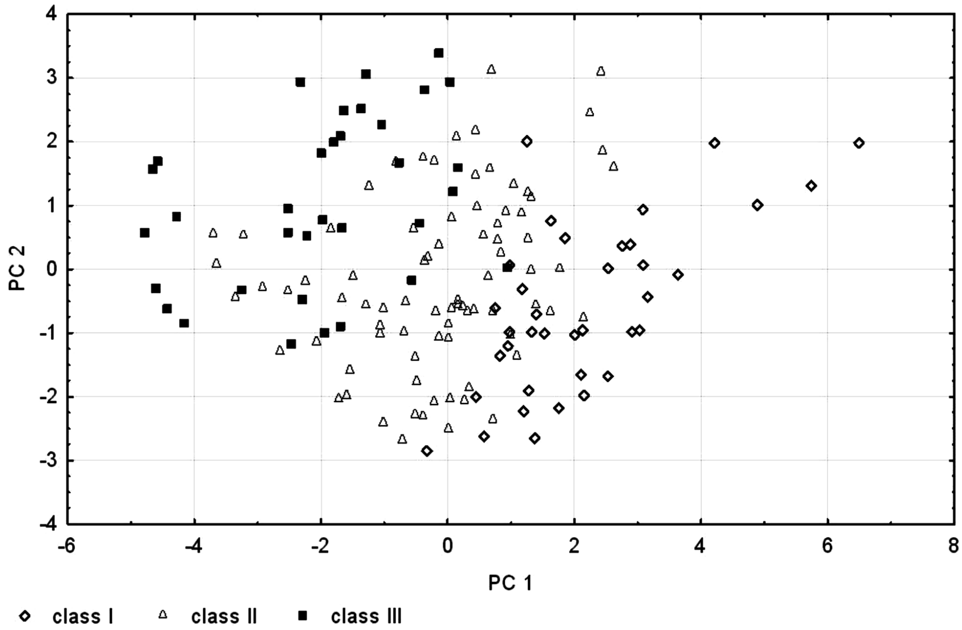

Fig. 2. Principal Component (PC) plot: age classes of fallow deer.

height of the ramus. For that reason, PC1 can be called the Component of the Size of the Mandible.

Studies on mandibular parameters in the fallow deer were conducted among others on the New Zealand's population by Nugent and Frampton (1994). However, the authors included only five parameters. It was concluded that the mandible growth becomes stabilized in females at the age of four. Nevertheless, the process of thickening lasts longer, especially in the vicinity of the diastema. Our studies indicate that the stage of mandible growth is much longer. The features included in this process are related not only to length (measurements Nos 1, 4, 8) but also to the height of the mandibular ramus (measurements No. 9). It can be assumed that this rule exists also in other species of Cervidae because Bertouille and Crombrugghe (2002) showed the variability of mandible length in the red deer. Based on the above studies, it was concluded that this parameter is also correlated with other features, such as fertility, that are seemingly unrelated.

In our study PC2 is strongly linked only with two measurements which relate to the length of the cheektooth row and length of the corpus. For that reason PC2 can be called the Component of tooth row. The standard method of age estimation used in hunting is based on tooth wear. Microscopic methods based on cross-sections of teeth are also available (Azorit *at al*. 2002, Iinuma *et al*. 2004). However, in the PCA method, we only used the metric features of a tooth row. Regardless of the fact that PC2 is a strong component, it does not show any relationship with the age of the examined animals.

Principal Components Analysis and eviscerated carcass mass

The last stage of this analysis was to examine the interrelations of the mandible parameters with the mass of eviscerated carcass. The PCA procedure was the same as above, but we chose a new grouping variable. Therefore, on the same two-dimensional graph in place of age classes indicators, there are indicators which characterize the carcass. The plot demonstrates this time that the new variable also has an effect on the grouping of mandibles. In grouping female fallow deer in relation to carcass mass, we adopted an assumption that each class is contained within a range of 4 kg. Only the last group "very heavy" was contained in a range of 3 kg (Fig. 3). Compared to the previous group, the chart showed that the animals classified as "very heavy" do not always belong to the III age class. The heaviest animals are usually of average age with medium mandibular parameters. Nevertheless, a moderate trend of mandibular parameters grew together with mass. Pearson's correlation coefficients confirm the existence of these interrelations (Table 2). Figure 4 and 5 present some characteristics correlated with age and caracass mass.

Table 2. Correlations between metric features of the mandible and carcass mass of fallow deer. Levels of significance: * p≤0.05, ** p ≤ 0.01.

No.	Metric feature	Carcass mass
1	Total length	0.52 **
2	Length of the ramus	0.00
3	Length of the corpus	0.14
4	Length without diastema and incisors	0.27 *
5	Length of the cheektooth row	-0.14
6	Length of the third molar	0.30 *
7	Breadth of the third molar	0.44 **
8	Length of the diastema	0.36 **
9	Middle height of the ramus	0.43 **
10	Height of the corpus behind the third molar	0.00
11	Height of the corpus in front of the first molar	0.20 *
12	Height of the corpus in front of the first premolar	0.07
13	Thickness of the corpus in front of the first molar	0.23 *
14	Breadth of the condyloid process	0.30 *
15	Thickness of the condyloid process	0.12

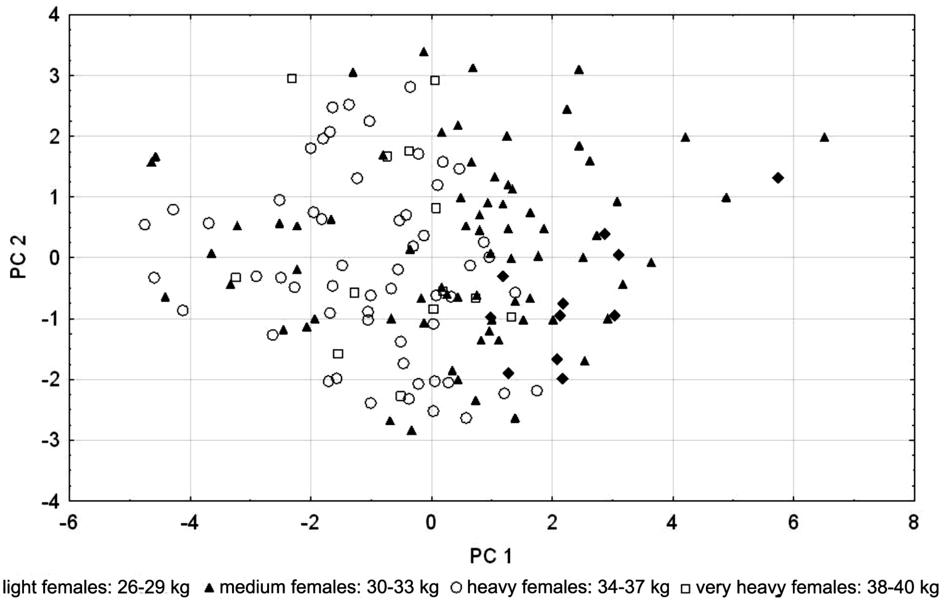

Fig. 3. Principal Component (PC) plot: weight classes of fallow deer eviscerated carcass mass.

Anatomical features of the mandible and teeth in ungulates are evidently related to the way they feed as well as the type of food a particular species prefers. When this subject is analyzed in the light of the even-toed ungulates and the deer, it should be concluded that there is a strong correlation between the mandible size and body mass (Raia *et al*. 2010). For that reason, it can be indirectly concluded that there is a correlation between the mandible and the body or carcass mass. Our studies confirm this fact. However, it should be emphasized that the correlation is not strong in all cases. The body mass of an adult deer may be subject to changes both in the course of a given calendar year and during the years to follow (Komosa *et al*. 2013). To a large extent, the increase of body mass is related to the increase of the amount of adipose tissue that occurs with age. Nevertheless, large fluctuations of body mass can occur depending on the availability of food in a given calendar year (Weckerly *et al*. 1987). Moreover, the daily activity of the deer is changing significantly depending on the season (Scheibe *et al*. 1999, Berger *et al*. 2002). Seasonal changes in food availability combined with the changes in physical activity evidently affect the changes in the proportions between the body or

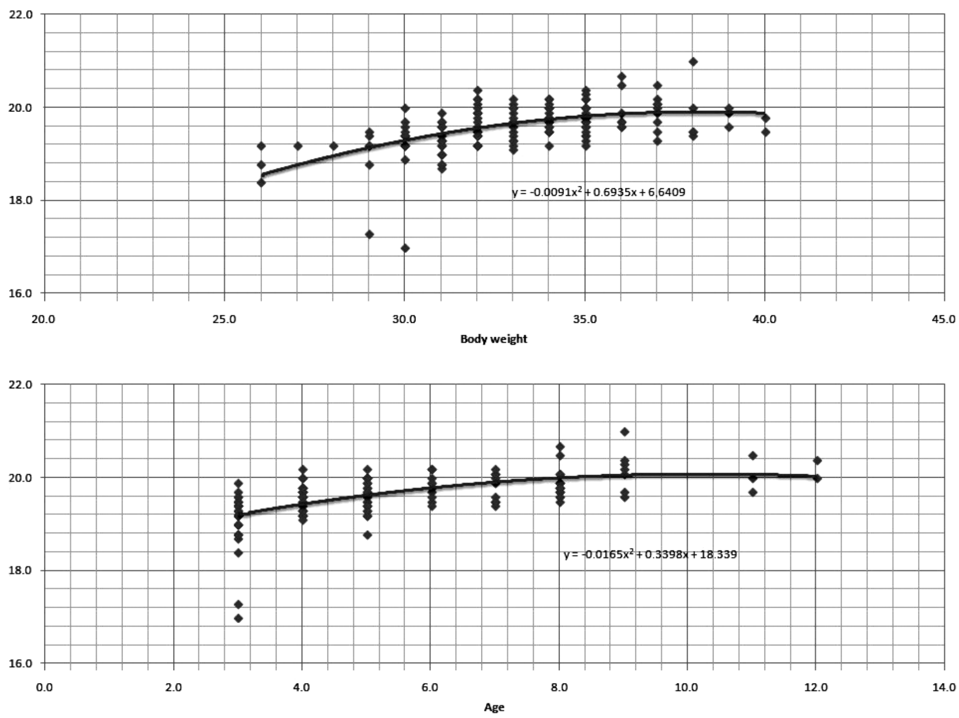

Fig. 4. Correlation between total length and carcass mass (above) and age (down) of fallow deer.

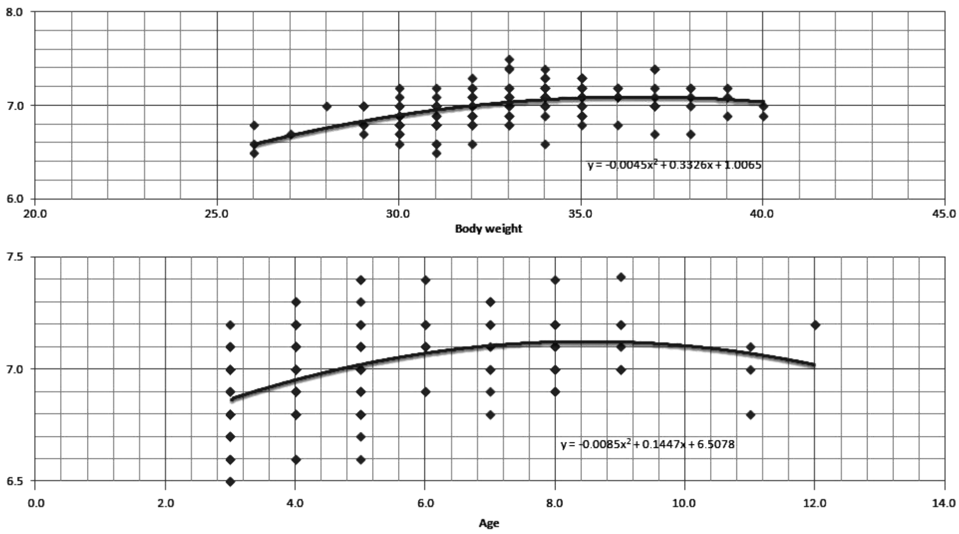

Fig. 5. Correlation between middle height of the ramus and carcass mass (above) and age (down) of fallow deer.

carcass mass and mandibular parameters. This is why the correlation that we describe is rather a trend than an unconditional correlation – see trend line on the Figures 4 and 5.

CONCLUSIONS

Metrical features of the mandible are related to the age classes of the fallow deer. Among the osteometric parameters the following ones are of particular importance: total length and middle height of the ramus.

There are significant correlations between some mandibular parameters and the eviscerated carcass mass of the female fallow deer. The highest correlations (about 0.5) occur between the eviscerated carcass mass and the following features: total length and the breadth of the third molar.

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