Acta Zoologica Academiae Scientiarum Hungaricae 65(1), pp. 63–73, 2019
DOI: 10.17109/AZH.65.1.63.2019

MORPHOMETRIC DISCRIMINATION BETWEEN AGE GROUPS OF *MARTES FOINA* (MUSTELIDAE, CARNIVORA) BY USING BACULUM IN TURKEY

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Martes foina has a wide range in Turkey. Identification of age groups in stone marten requires considerably hard procedures as well as in other carnivorous species. The present study is based on eight characteristic measurements from bacula of 41 samples obtained from all geographical regions of Turkey between 1995 and 2016. The goal is to discriminate young, juvenile, and adult individuals of stone marten using measured characteristics of the bacula. Analyzes revealed significant differences between young and adult samples. The characteristic, with the closest and lowest variability between age groups, is the total length of the baculum. The variation coefficient of this feature in young, juvenile, and adult individuals is 4.92%, 6.73%, and 3.90%, respectively. By using Linear Discriminant Analysis, juveniles were discriminated by 94.1% and adults by 95.5%. The samples which were ordered by describing with respect to the morphology of skull and shape and size of baculum at the beginning were grouped as 2 youngs, 17 juvenile individuals, and 22 adult individuals as a result of the analysis. Two baculum index, BI and BInew, were calculated for age groups. The indices were coherent. BI values of the adults were <6.65;7.78> and within the standards of the Italian population.

Keywords: Stone marten, os penis, morphometric analysis, mustelids.

INTRODUCTION

The baculum (os penis) is an extraskeletal bone found in certain species of Primates as well as species belonging to the orders Lipotyphla, Rodentia, Chiroptera, and Carnivora from Mammalia (Kratochvil & Kratochvil 1976, Lariviére & Ferguson 2002, Dixson & Anderson 2004, Krawczyk & Malecha 2009, Sharir *et al.* 2011, Schwery *et al.* 2011). It shows significant morphological differences between species concerning shape and size (Baryshnikov *et al.* 2003) and particularly between closely related species in carnivores (Hosken *et al.* 2001, Baryshnikov *et al.* 2003, Ramm 2007, Schulte-Hostedde *et al.* 2011, Vercillo & Ragni 2011). Two hypotheses were suggested describing the reason of morphological differences in baculum (Lupold *et al.* 2004). The first one of these hypotheses explains pleiotropic variation of baculum, and the latter explains the role of it during copulation (Miller *et al.* 1999, Kelly 2000, Baryshnikov *et al.* 2003, Ramm 2007). Therefore, it is used as a distinctive characteristic between species in taxonomy (Baryshnikov & Abramov 1997, 1998, Abramov & Baryshnikov 2000, Baryshnikov *et al.* 2003, Vercillo & Ragni 2011). Baculum also displays significant variations between individuals of a species (Reinwald 1961, Miller & Burton 2001, Dyck *et al.* 2004, Krawczyk *et al.* 2011, Čanády 2013).

Bacula of species belonging to Mustelidae have a considerably variable structure and certain complex spurs in distal ends (Baryshnikov *et al.* 2003). *Martes foina* belonging to this family has a wide area of distribution in Turkey and chooses different ecosystem types as habitat (Özen 1999, Özen & Gündüz 2017). Morphological variability in baculum of stone marten was studied in populations of Italy (Vercillo & Ragni 2011), Czech Republic (Čanády & Onderková 2016) and Turkey (Özen 2018). A study was conducted about the identification of age groups based on morphological differences in skull and bacula of *Martes foina* (Albayrak *et al.* 2008). However, discrimination of age groups by utilizing morphometric characteristics of baculum of this species has never been studied so far. Besides, identification of age groups has substantial importance for explaining population dynamics of a species and determining "protection strategy for species" in a possible period when it is endangered.

The goal of the present study is to reveal numeric data of characteristics of baculum for *Martes foina* in Turkey's population and to ensure complete discrimination between age groups by statistically analyzing the correlations between these data.

MATERIAL AND METHODS

Analyses were carried out on bacula of 41 samples of *Martes foina*. The samples were obtained dead from all geographical regions and 16 provinces of Turkey (Table 4) within the scope of two projects conducted between 1995 and 2016.

Body weights (g), standard somatic measurements; head-body length, hind foot length, tail length, and ear height (all in mm) of all samples were recorded. The bacula were treated according to Walton 1968, then washed with water, dehydrated in the air, and stored in museum boxes. While total length, base width, and apex width of the baculum were measured according to Walton 1968, other characteristics were measured by the author of the article. Totally eight characteristics of the bacula including weight were measured (Fig. 1).

While weights of the bacula were measured with a digital scale with 0.01 gr of precision, their lengths were measured with Vernier caliper with 0.02 mm precision. The samples were first described based on the shape of sagittal crest and clarity of lambdoidal crest in the skull (Albayrak *et al.* 2008) and the total length of the baculum (Suminski 1968, Walton 1968). Measured characteristics of the samples were statistically compared.

Baculum characteristics of juvenile and adult individuals were tested by t-test. Discrimination of all samples as juvenile or adult except for two young was also approved by Linear Discriminant Analysis (LDA).

Eventually, because it is thought that total length of baculum is affected by the size of individual and base length of baculum is also influenced by total length of baculum, baculum index was calculated by using BI (Baculum Index) = Head + Body Length (HBL) / Total Length of Baculum (TL) and BInew (Baculum Indexnew) = Total Length of Baculum (TL) / Base Length of Baculum (BL). A t-test was performed for juvenile and adults. Since the sample number of young is extremely limited, the data of juvenile and adult individuals were used in the analysis. Sample size showed insignificant differences due to the partial loss in two materials.

The obtained data set was evaluated using the statistical parameters: range margins (min-max), mean ($\bar{x}$), standard deviation (SD), standard error (SE), and coefficient of variation (CV). All analyses were performed by using SPSS 24 (IBM Corp., Armonk, NY, USA). Normality of all characteristics was tested by using Shapiro-Wilk W test (under all circumstances $P > 0.01$) and showed normal distribution. While BI was calculated according to Vercillo and Ragni (2011), BInew was calculated by the author of the present article.

RESULTS

Baculum of *Martes foina* was derived from a mustelid baculum in the form of a simple stick without decorations on urethral tract and the distal end (Baryshnikov *et al.* 2003). In the distal part of baculum, has a structure similar to the birds head. Middle of this structure had an open ellipsoid area. However, baculum of *Martes foina* shows some morphological differences in young, juvenile, and adult individuals (Fig. 2).

The values of baculum characteristics from two young samples, one was 3.5 months old, and the other one was 4.5 months old on the records of the collection, were taken as reference for morphological discrimination of bacula (Table 1).

There were significant differences between juvenile and adult samples concerning weight, total length, base length, base height, base width, and apex

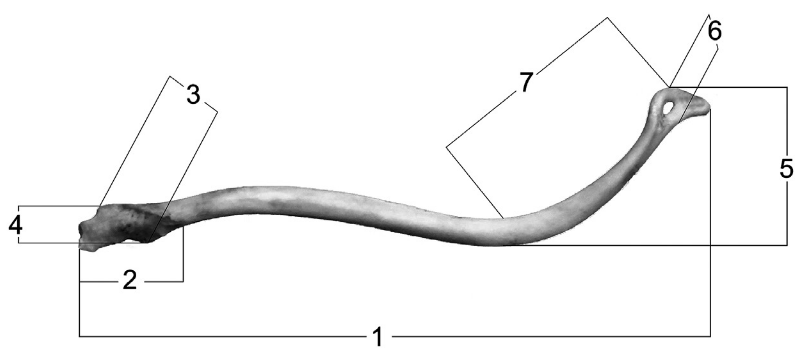

Fig. 1. Measurements taken in the baculum of *Martes foina*. 1 = total length (TL), 2 = base length (BL), 3 = base height (BH), 4 = base width (BW), 5 = apex height (AH), 6 = apex width (AW), 7 = slope length (SL)

Table 1. Descriptive statistics of measured baculum traits of young individuals of *Martes foina*. Weight in grams, others in millimetres, n = sample size, min-max = range margins, $\bar{x}$ = mean, SD = standard deviation, CV = coefficient of variation. For abbreviations of baculum variables see Fig. 1.

Traits	n	min-max	$\bar{x}$±SD	CV
BP	2	0.11-0.16	0.14±0.04	26.19
TL	2	40.35-43.26	41.81±2.06	4.92
BL	2	2.01-2.21	2.11±0.14	6.7
BH	2	1.83-2.19	2.01±0.25	12.66
BW	2	2.17-2.23	2.2±0.04	1.93
AH	2	11.79-13.65	12.72±1.32	10.34
AW	2	3.43-3.48	3.46±0.04	1.02
SL	2	18.3-18.97	18.64±0.47	2.54

width of bacula ($P < 0.01$), insignificant differences between them in terms of apex height and slope length ($P > 0.01$). The coefficient of variation (CV) is an indicator for morphometric variability of bacula and has been described as the ratio of standard deviation to mean (Table 2).

In juvenile and adult samples, means of apex height and slope length characteristics and coefficients of variation (CV) of the baculum were similar. Therefore, the values of these two characteristics of the bacula during both periods of age were considered to be maintained.

Fig. 2. Typical baculum structure at the young (a) juvenile (b) and adult (c) individuals of *Martes foina*

Table 2. A comparison of measured baculum traits between juvenile and adult individuals of *Martes foina*. Weight in grams. others in milimetres. n: number of sample. min-max: range margins. $\bar{x}$ = means. SD = standard deviation, CV = coefficient of variation. For abbreviations of baculum variables see Fig. 1.

Traits	Juveniles				Adults					
	n	min–max	$\bar{x}$±SD	CV	n	min–max	$\bar{x}$±SD	CV	t-test	P
BP	16	0.11–0.30	0.24±0.05	23.16	22	0.38–0.67	0.53±0.09	16.62	11.7	<0.01
TL	16	44.22–58.09	52.58±3.54	6.74	22	56.98–66.06	60.87±2.38	3.91	8.63	<0.01
BL	16	2.45–5.27	4.18±0.82	19.66	22	5.79–9.79	7.82±0.97	12.41	12.16	<0.01
BH	16	1.63–3.05	2.37±0.40	16.86	22	2.48–5.50	4.26±0.81	18.96	9.47	<0.01
BW	16	1.72–3.89	2.60±0.62	23.97	22	2.90–6.10	4.50±0.74	16.46	8.36	<0.01
AH	17	6.50–14.07	11.06±1.81	16.34	22	8.34–15.41	11.04±1.87	16.91	–0.03	>0.01
AW	17	3.22–3.89	3.48±0.20	5.82	22	3.28–4.65	3.84±0.37	9.7	3.65	<0.01
SL	17	10.02–20.85	16.93±2.55	15.08	22	12.87–20.31	16.76±1.75	10.45	–0.24	>0.01

As a result of Linear Discriminant Analysis performed by utilizing six characteristics of the baculum (those are $P < 0.01$), the grouping was approved by 94.1% for juvenile and 95.5% for adults (Table 3).

The characteristics with the closest and lowest variability between age groups are the total length of baculum. Therefore, this characteristic was predicted to be used as a parameter for index formulas. Both characteristics of baculum used for index equation and the values of the index were recorded (Table 4).

Table 3. Results of Linear Discriminant Analysis. which allows juvenile and adult samples to be separated from each other in *Martes foina*[a, c].

		Predicted group membership			
		Age	Adult	Juvenile	Total
Original	Count	Adult	22	0	22
		Juvenile	1	16	17
	%	Adult	100	0	100
		Juvenile	5.9	94.1	100
Cross-validated[b]	Count	Adult	21	1	22
		Juvenile	1	16	17
	%	Adult	95.5	4.5	100
		Juvenile	5.9	94.1	100

[a] 97.4% of original grouped cases correctly classified.
[b] Cross validation is done only for those cases in the analysis. In cross validation each case is classified by the functions derived from all cases other than that case.
[c] 94.9% of cross-validated grouped cases correctly classified.

Table 4. Sample localities (provinces), base length (BL), of the baculum, total length (TL), head-body length (HBL) , BI and BInew values.

Sample no	Locality	BL	TL	HBL	BI	BInew
1	Kütahya	2.01	40.35	385	9.54	20.07
2	Çorum	2.21	43.26	411	9.50	19.57
3	Balıkesir	2.45	44.22	386	8.73	18.05
4	Balıkesir	4.39	48.45	405	8.36	11.04
5	Denizli	3.28	48.77	440	9.02	14.87
6	Adıyaman	4.62	50.32	410	8.15	10.89
7	Balıkesir	4.52	51.27	405	7.90	11.34
8	Adana	4.49	51.69	470	9.09	11.51
9	Kütahya	4.66	52.29	410	7.84	11.22
10	Kütahya	3.48	52.33	460	8.79	15.04
11	Malatya	4.84	53.25	460	8.64	11.00
12	Balıkesir	4.22	53.44	455	8.51	12.66
13	Balıkesir	3.55	54.22	423	7.80	15.27
14	Adıyaman	5.19	54.32	445	8.19	10.47
15	Bingöl	3.22	55.39	450	8.12	17.20
16	Bingöl	3.58	55.98	450	8.04	15.64
17	Erzurum	-	56.98	440	7.72	-
18	Balıkesir	5.09	57.29	459	8.01	11.26
19	Balıkesir	7.22	57.94	423	7.30	8.02
20	Erzurum	5.27	58.09	460	7.92	11.02
21	Aydın	8.38	58.34	430	7.37	6.96
22	Burdur	7.44	58.55	440	7.51	7.87
23	Balıkesir	7.28	59.12	450	7.61	8.12
24	Manisa	9.46	59.39	460	7.75	6.28
25	Bayburt	7.64	59.80	465	7.78	7.83
26	Balıkesir	8.21	59.89	450	7.51	7.29
27	Balıkesir	7.52	59.90	460	7.68	7.97
28	Konya	7.57	60.00	450	7.50	7.93
29	Konya	8.35	60.12	410	6.82	7.20
30	Balıkesir	6.00	60.32	459	7.61	10.05
31	Balıkesir	6.36	60.45	442	7.31	9.50
32	Balıkesir	7.86	61.22	407	6.65	7.79
33	Adıyaman	7.94	61.30	430	7.01	7.72
34	Hatay	8.64	61.73	460	7.45	7.14
35	Adıyaman	8.22	61.88	440	7.11	7.53

Table 4 (continued)

Sample no	Locality	BL	TL	HBL	BI	BInew
36	Kütahya	7.67	63.00	430	6.83	8.21
37	Kütahya	7.68	63.03	460	7.30	8.21
38	Balıkesir	8.53	65.00	456	7.02	7.62
39	Konya	8.56	65.12	460	7.06	7.61
40	Antalya	9.79	66.06	450	6.81	6.75
41	Balıkesir	-	-	-	-	-

Table 5. Descriptive statistics for BI and BInew in young samples. n: sample size. min-max: range margins. $\bar{x}$: mean. SD: standard deviation and parenthesized coefficient of variation (CV).

Index	n	min-max	$\bar{x}$±SD
BI	2	9.50–9.54	9.52±0.03 (0.303)
BInew	2	19.57–20.07	19.82±0.35 (1.78)

In BI among identification criteria, juveniles with sample numbers 18 and 20 had a standard deviation among the adult group (Fig. 3).

In BInew which is one of the recommended criteria of identification, no standard deviation was seen for two juvenile samples in BI, and the samples were divided into three distinct groups (Fig. 4). Besides, sample number 3 was evaluated as young according to both indexes.

In the young group, standard values of BI and BInew were <9.50; 9.54> and <19.57; 20.07>, respectively (Table 5).

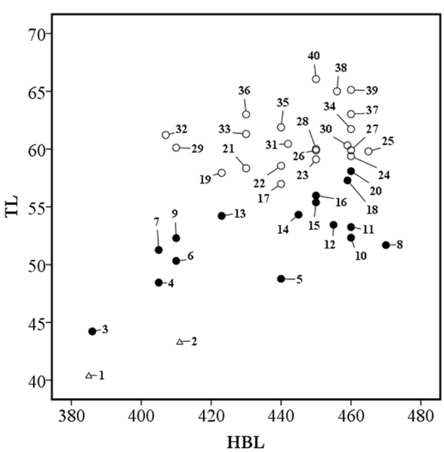

Fig. 3. Plot of TL vs HBL. Young: triangles; juvenile: black circles; adult: white circles. The numbers represent sample no

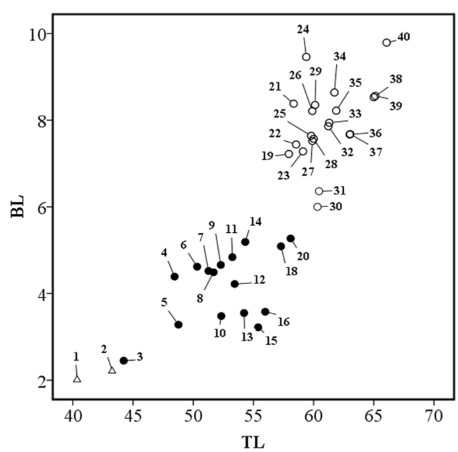

Fig. 4. Plot of BL vs TL. Young: triangles; juvenile: black circles; adult: white circles. the numbers represent sample numbers

Table 6. Descriptive statistics for BI and BInew in juvenile and adult samples. n: sample size. min-max: range margins. $\bar{x}$: mean. SD: standard deviation and parenthesized coefficient of variation (CV).

Index	Juvenile			Adult			t-test	P
	n	min-max	$\bar{x}$±SD	n	min-max	$\bar{x}$±SD		
BI	16	7.80–9.09	8.32±0.42 (5.11)	22	6.65–7.78	7.30±0.34 (4.69)	-8.13	<0.01
BInew	16	10.46–18.04	13.02±2.53 (19.43)	22	6.28–10.05	7.88±0.92 (11.67)	–7.74	<0.01

BI and BInew showed a significant (P< 0.01) difference for juvenile and adult individuals (Table 6).

Standard values of BI were <7.80;9.09> for juvenile and <6.65;7.78> for adults. The area of discrimination between both age groups was wide (t = 8.13, df = 36 and P < 0.01) (Fig. 5A). Standard values of BInew were <10.46;18.04> for juvenile and <6.28;10.05> for adults. Similarly, the area of discrimination between both age groups of BInew as like BI was wide (t = 7.74, df = 36 and P < 0.01) (Fig. 5B).

Standard values revealed in both index included samples described according to the morphological features of the skull and the baculum.

DISCUSSION

BI value calculated for adult samples of *Martes foina* were in the range of standards (<6.24;8.10>) given for the Italian population (Vercillo & Ragni 2011). Other studies were not compared with the results of the present study because BI data were not determined for young and juvenile age groups. Additionally, the means of weight (0.43±0.15), total length (56.01±3.83), base

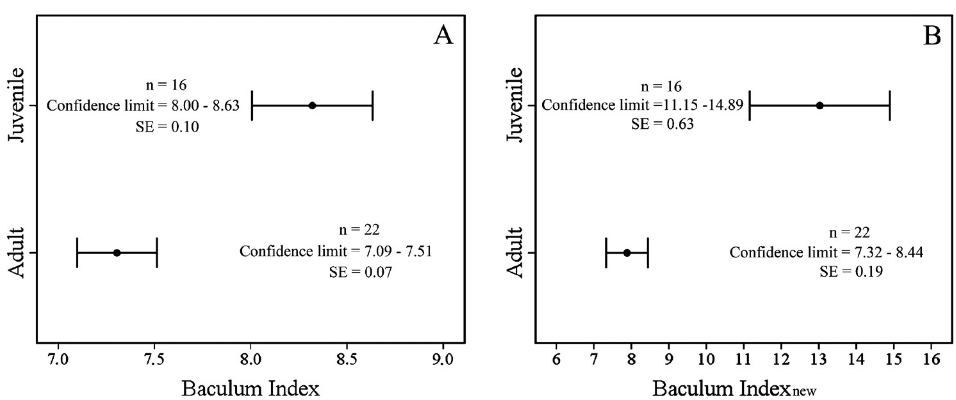

Fig. 5. Plot means and descriptive statistics of BI (A) and BInew (B). n: sample size. SE: standard error and black points represent the average age group (preferred confidence interval is 99%).

height (3.80±1.07) and base width (2.73±0.84) were lower in bacula of *Martes foina* population in Czech Republic (Čanády & Onderková 2016) than Turkish population.

The samples, which were ordered by being described based on characteristics of skull and length of baculum at the beginning, were divided as 2 youngs, 17 juvenile individuals, and 22 adult individuals based on the results of the analysis. Adult individuals represent morphological characteristics of a species best. The most crucial factor in morphometric incompatibility occurring in different populations of the same species is assumed to be hidden in the criteria used for discrimination of juvenile and adult individuals. Therefore, discrimination of juvenile ones among adults has considerable importance to increase the reliability of morphometric analyses regarding a species.

Skull characteristics (Albayrak *et al.* 2008) and the length of the baculum (Suminski 1968, Walton 1968) are considered as an identification tool for the determination of age groups of carnivorous species. However, BI and BInew, which are based on account of morphometric features of the baculum, were appeared to be a more reliable method. BInew separates age groups more precisely than BI.

As a result, the classifications made according to the morphometric features can be very useful for identifying the ages of individuals in *Martes foina*. Correct identification of age groups has substantial importance for explaining population dynamics of a species and preparing "action plan for protecting species" in a period when it is endangered.

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Acknowledgements – My thanks include two anonymous reviewers for precious and significant evaluations of the manuscript.

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Received December 4, 2018, accepted February 9, 2019, published March 18, 2019