

1-1-2017

Biometric variation in *Martes foina* from mainland Greece and the Aegean Islands

MALAMATI PAPAKOSTA

Follow this and additional works at: <https://journals.tubitak.gov.tr/zoology>



Part of the [Zoology Commons](#)

Recommended Citation

PAPAKOSTA, MALAMATI (2017) "Biometric variation in *Martes foina* from mainland Greece and the Aegean Islands," *Turkish Journal of Zoology*. Vol. 41: No. 4, Article 8. <https://doi.org/10.3906/zoo-1612-8>
Available at: <https://journals.tubitak.gov.tr/zoology/vol41/iss4/8>

This Article is brought to you for free and open access by TÜBİTAK Academic Journals. It has been accepted for inclusion in Turkish Journal of Zoology by an authorized editor of TÜBİTAK Academic Journals. For more information, please contact academic.publications@tubitak.gov.tr.

Biometric variation in *Martes foina* from mainland Greece and the Aegean Islands

Malamati A. PAPAĞOSTA*

Laboratory of Wildlife & Freshwater Fisheries, Department of Forestry and Natural Environment, Aristotle University of Thessaloniki, Thessaloniki, Greece

Received: 06.12.2016 • Accepted/Published Online: 08.03.2017 • Final Version: 17.07.2017

Abstract: The geographical morphometric variations in the stone marten (*Martes foina*) from mainland Greece, the Aegean Islands, and Crete were analyzed. Samples taken from the three areas were compared regarding 18 craniometrical and 5 body size variables. According to univariate statistics, 13 skull measurements from males and 15 from females (72% and 83% of total skull variables for males and females, respectively) did not differ significantly among mainland Greece, the Aegean Islands, and Crete. The morphological differences among mainland and insular populations showed a tendency for separation (63% overall correct classification from skull measurements of males, 72.5% and 73.6% for body measurements of males and females, respectively). The resulting weak morphological variation in the stone marten does not favor the presence of a subspecies in Greece and suggests that insular populations are not endemic and belong to the same population from the mainland. Genetic analysis is needed for the revision of the taxonomy of the species in the Mediterranean area.

Key words: *Martes foina*, morphology, skull, body size, stone marten

1. Introduction

The stone marten (*Martes foina*) is one of the most widely distributed mustelids in the Eurasian region (Genovesi et al., 1996), inhabiting areas from Spain and Portugal in the west, through Central and Southern Europe, the Middle East and Central Asia, and extending as far east as northwest China (Abramov et al., 2016). The species probably entered Europe from the Near East at the end of Pleistocene or in early postglacial times (Anderson, 1970). The stone marten is the most-dispersed carnivore in the Eastern Mediterranean islands, where it ranges from the Ionian to the Dodecanese, through most of the Aegean Islands, and Crete (Masseti, 1995a; Ragni et al., 1999). It occupies a variety of habitats and is documented as food generalist (Serafini and Lovari, 1993; Papakosta et al., 2014).

As McDonald and King (2000) note, the taxonomy of the majority of mustelids is in need of revision. The stone marten, within its range, is classified into 11 subspecies. This classification is under debate because it was based only on morphological characteristics (e.g., extension and pattern of throat patch) from a few specimens (Yiğit et al., 1998; Kryštufek, 2004a, 2004b). Only recently has there been an attempt to study the population genetic

structure of the stone marten at a country level in the Iberian Peninsula (Vergara et al., 2015). The stone marten in mainland and insular Greece is considered to occur with three subspecies: *Martes foina foina*, *M. f. bunites* (Bate, 1905), and *M. f. milleri* (Festa, 1914). There is no genetic background, though, to support this taxonomic differentiation. *M. f. bunites* has an irregular whitish throat patch, sometimes greatly reduced or almost not visible. Moreover, it is smaller than *M. f. foina*. *M. f. milleri* has almost the same body size as *M. f. bunites*, but has a more extensive throat patch and less yellowish upper parts (Douma-Petridou, 1984).

Size is one of the most significant characteristics of an animal, as it is related to its life-history patterns (Calder, 1996) and thus morphological variation studies are of great interest. There is increasing evidence of high intraspecific body size variation spatially and temporally. These differences are usually related to food availability, prey size, and intraspecific competition (Fuentes and Jaksic, 1979; King, 1991; Rosatte et al., 1991).

Understanding patterns and differences in stone marten morphology are crucial for the revision of its taxonomy and could contribute to its management and conservation.

* Correspondence: mpapakosta@for.auth.gr

The aims of the present study were: 1) to compare, from a morphological point of view, the stone marten from mainland Greece with other populations of the species on the Aegean Islands and Crete, 2) to assess whether the three putative stone marten subspecies can be confirmed from univariate and multivariate skull and body size analyses, and 3) to give a quantitative description of its skull that will allow future comparisons (in paleontology, zoogeography, etc.).

2. Materials and methods

A total of 87 skull specimens of adult stone martens (52 males, 35 females) from mainland Greece, Crete, and the Aegean Islands (Kykklades, Dodekanisa, and the Northeast Aegean) were examined. Thirty-eight skull specimens originated from mainland and 49 from insular Greece. Specimens were pooled by area-group and sex to form comparable samples. The age-class classification was made by the shape of the temporal ridges on the skull (Albayrak et al., 2008). Body size measurements were based on 215

individuals (109 males, 106 females). One hundred and nineteen specimens used for body size measurements originated from the mainland and 96 from insular Greece. The distribution the specimens is shown in Figure 1. Collected samples were mainly run over by cars on roads or shot by hunters. Skull measurements were taken using an electronic scanner (Next Engine Mini HD Laser Scanner; Santa Monica, CA, USA) to maximize accuracy (Aung et al., 1995; Sholts et al., 2011). Eighteen cranial and mandible variables from the dorsal, ventral, and lateral view of the cranium and the lateral view of the mandible were measured (Figure 2). Moreover, five body size variables were measured: body length, tail length, body height, and ear length in millimeters and body weight in grams.

Univariate statistics were used to estimate mean, standard error, and F-values obtained by one-way analysis of variance for each morphometric variable per sample area and per sex. All variables were tested for homogeneity of variance and normality using Levene and Kolmogorov-



Figure 1. Distribution of stone marten specimens from mainland (1. Province of Evros, 2. Central Macedonia, 3. Western Macedonia, 4. Thessaly, 5. Sterea Hellas, 6. Peloponnisos) and insular Greece (Andros, Crete, Lesvos, Naxos, Paros, Rhodes, Kea, Kythnos).

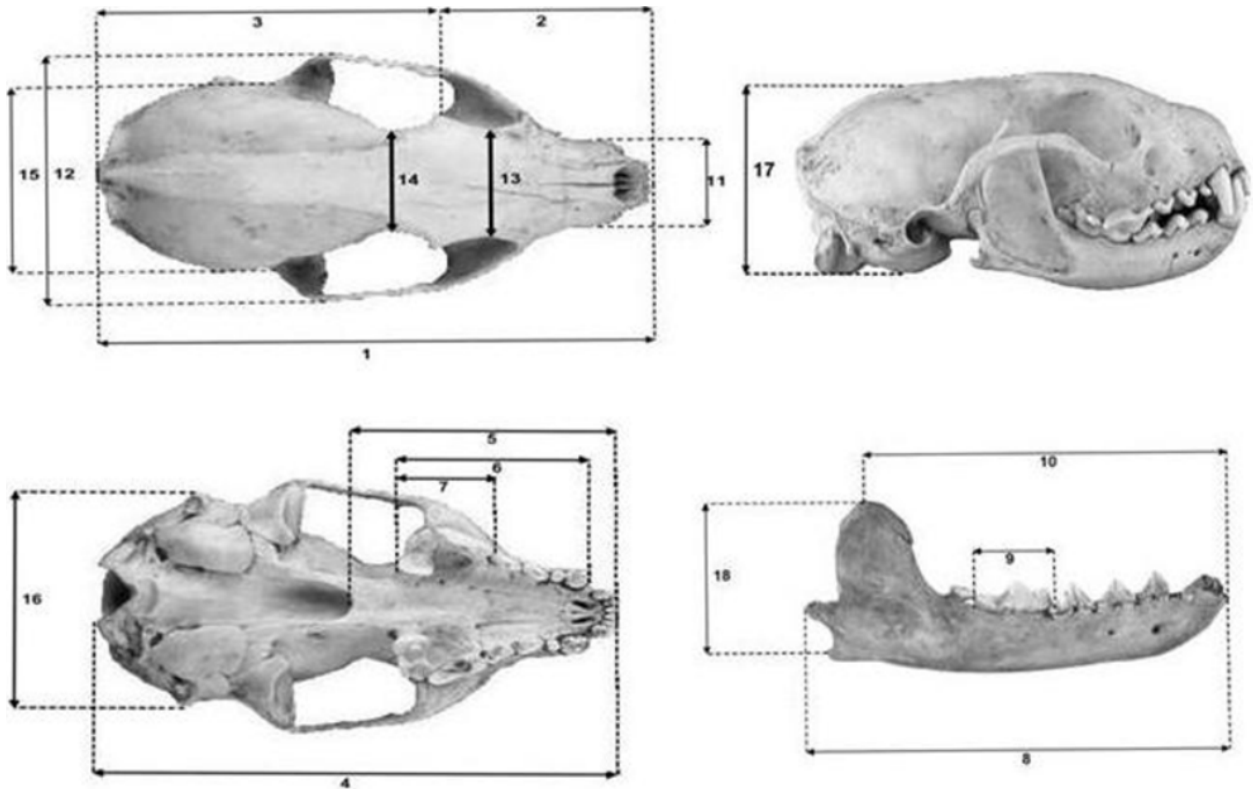


Figure 2. Skull measurements of stone marten: 1. skull length (S-L), 2. facial length (F-L), 3. upper neurocranium length (UpNrc-L), 4. condylobasal length (Cb-L), 5. palatal length (Pa-L), 6. length of maxillary tooth row (MaxT-L); 7. length of the molar row (Mo-L); 8. mandible condyle length (MaCond-L), 9. length of carnassial tooth (CaT-L), 10. mandible coronoid process length (MaCorP-L), 11. width of rostrum (Ro-W), 12. zygomatic breadth (Zy-B), 13. interorbital breadth (InOrb-B), 14. postorbital breadth (PosOrb-B), 15. breadth of braincase (Brc-B), 16. distance between mastoid processes (MaP-Di), 17. cranium height measured from the auditory bulla (CrAuB-H), 18. angular process coronoid process distance (AnPCorP-Di).

Smirnov tests. Variables that did not meet the above assumptions were transformed or a nonparametric test (Kruskal–Wallis) was used (Zar, 1996). Males and females were examined separately due to the sexual dimorphism of the species (Holmes and Powell, 1994). If differences occurred among the three sampling areas, pair-wise comparisons were applied using the Mann–Whitney test ($P < 0.017$, Bonferroni correction) (Rice, 1989).

Principal component analysis (PCA) was applied as an exploratory method to find association patterns among the variables used. Kaiser–Meyer–Olkin index (KMO: 0.5–1) and Bartlett’s test of sphericity ($P < 0.05$) measured sampling adequacy and detected whether or not the information provided by the initial variables could be summarized in a limited number of factors. From the original 18 skull variables, 11 were used in PCA, based on the selection criterion of variables (communalities values > 0.5).

To eliminate unnecessary skull variables, a stepwise selection procedure was run to select the most useful subset of discriminating variables. Discriminant analysis (DA)

was performed to distinguish whether different groups occurred and to clarify the morphological variations among the three sampling areas (mainland Greece, Crete, and the Aegean Islands). Box’s test of equality of covariance matrices and Wilks’s lambda test for variable contributions in discriminant functions were used. Cross-validation was used to give the percentage of classification into different groups.

All statistical analyses, univariate and multivariate, were performed with SPSS 15.0 and statistical tests were significant if $P < 0.05$.

3. Results

3.1. Skull measurements

According to univariate statistics, 13 skull measurements from males and 15 from females (72% and 83% of total skull variables for males and females, respectively) did not differ significantly among mainland Greece, the Aegean Islands, and Crete (Table 1), whereas only 5 skull measurements in males (Cb-L, CaT-L, MaCorP-L, Zy-B, Brc-B) and 3 in females (AnPCorP-Di, MaxT-L, UpNrc-L)

Table 1. Skull measurements (mean \pm SE) of female and male stone martens in three sample areas in Greece. Same letters (^a, ^b) indicate that there were no differences between the sample areas. Bold letters indicate that mean values were significantly larger than the same measurement in the other area or areas.

Measurement	Mainland		Aegean Islands		Crete		P-value	
	(n = 38)		(n = 39)		(n = 10)			
	Female (n = 15)	Male (n = 23)	Female (n = 18)	Male (n = 21)	Female (n = 2)	Male (n = 8)	Female	Male
S-L	79.74 \pm 0.81	81.54 \pm 0.75	78.46 \pm 0.57	83.43 \pm 0.59	78.07 \pm 0.42	82.01 \pm 0.36	0.506	0.119
F-L	30.95 \pm 0.45	32.05 \pm 0.38	30.59 \pm 0.28	32.60 \pm 0.25	32.04 \pm 0.93	31.96 \pm 0.30	0.219	0.375
UpNrc-L	49.30^a \pm 0.52	50.32 \pm 0.41	48.3^{ab} \pm 0.45	51.29 \pm 0.47	46.13 ^b \pm 0.24	49.48 \pm 0.46	0.044	0.065
Cb-L	74.77 \pm 0.64	76.68^{ab} \pm 0.42	73.21 \pm 0.51	77.76^b \pm 0.48	72.19 \pm 0.12	75.76 ^a \pm 0.34	0.100	0.036
Pa-L	38.41 \pm 0.39	39.58 \pm 0.25	37.58 \pm 0.38	40.36 \pm 0.36	37.57 \pm 0.75	40.17 \pm 0.25	0.247	0.161
MaxT-L	28.09^a \pm 0.22	28.94 \pm 0.16	27.26 ^b \pm 0.28	28.94 \pm 0.19	27.1^{ab} \pm 0.04	28.43 \pm 0.18	0.030	0.251
Mo-L	12.53 \pm 0.18	12.87 \pm 0.15	12.38 \pm 0.19	13.18 \pm 0.13	11.78 \pm 0.17	13.03 \pm 0.22	0.161	0.294
MaCond-L	51.03 \pm 0.54	52.78 \pm 0.41	50.17 \pm 0.43	53.97 \pm 0.30	49.73 \pm 0.24	53.12 \pm 0.24	0.618	0.089
CaT-L	9.52 \pm 0.13	10.07^{ab} \pm 0.09	9.15 \pm 0.10	9.84 ^a \pm 0.05	9.41 \pm 0.27	10.26^b \pm 0.05	0.117	0.002
MaCorP-L	43.32 \pm 0.42	44.97 ^a \pm 0.45	44.19 \pm 0.64	50.90^b \pm 0.58	48.81 \pm 0.19	46.70 ^a \pm 0.69	0.059	<0.001
Ro-W	17.20 \pm 0.22	17.98 \pm 0.17	16.57 \pm 0.15	17.86 \pm 0.15	16.73 \pm 0.07	17.68 \pm 0.10	0.110	0.562
Zy-B	47.28 \pm 0.41	48.61 ^a \pm 0.54	46.63 \pm 0.43	50.62^b \pm 0.38	45.79 \pm 0.55	50.15^{ab} \pm 0.58	0.224	0.009
InOrb-B	20.57 \pm 0.33	21.03 \pm 0.22	20.06 \pm 0.21	21.7 \pm 0.27	19.17 \pm 0.48	20.96 \pm 0.20	0.121	0.211
PosOrb-B	19.17 \pm 0.39	19.92 \pm 0.42	18.49 \pm 0.26	18.70 \pm 0.23	19.25 \pm 0.49	19.16 \pm 0.41	0.229	0.110
Brc-B	36.01 \pm 0.35	37.34^b \pm 0.23	35.11 \pm 0.27	36.49 ^a \pm 0.24	35.16 \pm 0.42	36.41 ^a \pm 0.25	0.050	0.018
MaP-Di	37.54 \pm 0.33	38.35 \pm 0.28	36.26 \pm 0.34	38.14 \pm 0.34	36.55 \pm 0.54	37.87 \pm 0.25	0.066	0.680
CrAuB-H	31.31 \pm 0.29	32.48 \pm 0.23	30.58 \pm 0.25	31.99 \pm 0.13	30.14 \pm 0.99	31.81 \pm 0.27	0.184	0.092
AnPCorP-Di	23.34^a \pm 0.26	23.80 \pm 0.32	21.53 ^b \pm 0.23	23.37 \pm 0.21	21.8^{ab} \pm 0.18	23.15 \pm 0.22	<0.001	0.331

were significantly different among the three areas ($P < 0.05$). Moreover, the above differences in the skulls of males and females arise from different skull variables for each sex. Almost all length-related skull measurements of males were larger in the Aegean Islands and, in contrast, almost all the skull measurements of females were larger in the mainland. Males had significantly larger condylobasal length (Cb-L) in the mainland and the Aegean Islands, mandible coronoid process length (MaCorP-L) in the Aegean Islands, carnassial tooth length (CaT-L) in Crete and the mainland, zygomatic breadth (Zy-B) in the Aegean Islands and Crete, and breadth of braincase (Brc-B) in mainland Greece. Females had significantly larger upper neurocranium length (UpNrc-L) in the mainland and the Aegean Islands, and length of maxillary tooth row (MaxT-L) and angular process coronoid process distance (AnPCorP-Di) in the mainland and Crete. PCA using skull measurements from male specimens created three factors that explained 76.44% of the total variance. KMO index and Bartlett's test of sphericity checked the sampling adequacy (KMO = 0.745, Bartlett's test, $P < 0.001$) so

the original variables could be factorized efficiently. PC1 was positively loaded on the length of skull and PC2 was mainly loaded on the width of skull. PC3 was highly correlated with zygomatic breadth (Table 2). In stepwise DA, the grouping variables covariance matrices were equal (Box's M, $P = 0.136$) and four skull measurements (Brc_B, Zy_B, Pa_L, Cb_L) were selected (Table 3). The first discriminant function (DF1) was correlated with the four discriminant variables (canonical correlation = 0.738) and there was a discrimination among individuals from the three sampling areas (eigenvalue = 1.197, Wilks's lambda = 0.368, $P < 0.001$). In contrast, DF2 expressed very weak correlation and discrimination among sample areas (canonical correlation = 0.438, eigenvalue = 0.238, Wilks's lambda = 0.808, $P = 0.038$). The plot of the centroids showed a tendency for separation in three groups: stone marten populations from mainland Greece, the Aegean Islands, and Crete (Figure 3). The selected variables correctly classified 63.0% (cross-validated grouped cases) of male skulls by sampling area (Table 4).

Table 2. Rotated principal component structure using the varimax rotation method for the first three components, eigenvalues, and cumulative contribution rate.

Skull measurements	Male		
	PC1	PC2	PC3
S_L	0.892	0.314	0.142
Pa_L	0.803	0.030	0.040
Cb_L	0.786	0.093	0.175
UpNrc_L	0.786	0.410	0.099
MaCond_L	0.756	0.280	0.315
Brc_B	0.238	0.746	0.119
AnPCorP_Di	0.138	0.726	0.144
PosOrb_B	0.091	0.714	-0.320
MaP_Di	0.171	0.701	0.317
InOrb_B	0.365	0.496	0.384
Zy_B	0.267	0.123	0.941
Eigenvalue	13.855	3.424	2.564
Cumulative contribution rate	0.403	0.584	0.764

Table 3. Standardized coefficients of the first two discriminant functions.

Skull variables	DF1	DF2
Brc_B	-1.136	-0.141
Zy_B	0.830	-0.127
Pa_L	0.650	-0.851
Cb_L	0.013	1.342
Eigenvalues	1.197	0.238
Variance explained %	83.4	16.6

3.2. Body size measurements

According to univariate statistics applied in body size variables, most measurements from both females and males (body weight, tail length, ear length, and body

height) were significantly larger in stone martens from mainland Greece ($P < 0.05$) (Table 5). The first discriminant function (DF1) is correlated with the body size variables (body weight, body length, tail length) (canonical correlation = 0.738) for both males and females (Table 6). There was discrimination among males from the three sampling areas (eigenvalue = 1.199, Wilks's lambda = 0.450, $P < 0.001$) and females (eigenvalue = 1.193, Wilks's lambda = 0.453, $P < 0.001$). In contrast, DF2 expressed very weak correlation with the discriminant variables and discrimination among populations from mainland Greece, the Aegean Islands, and Crete (Figures 4 and 5). The analysis correctly classified 72.5% and 73.6% (cross-

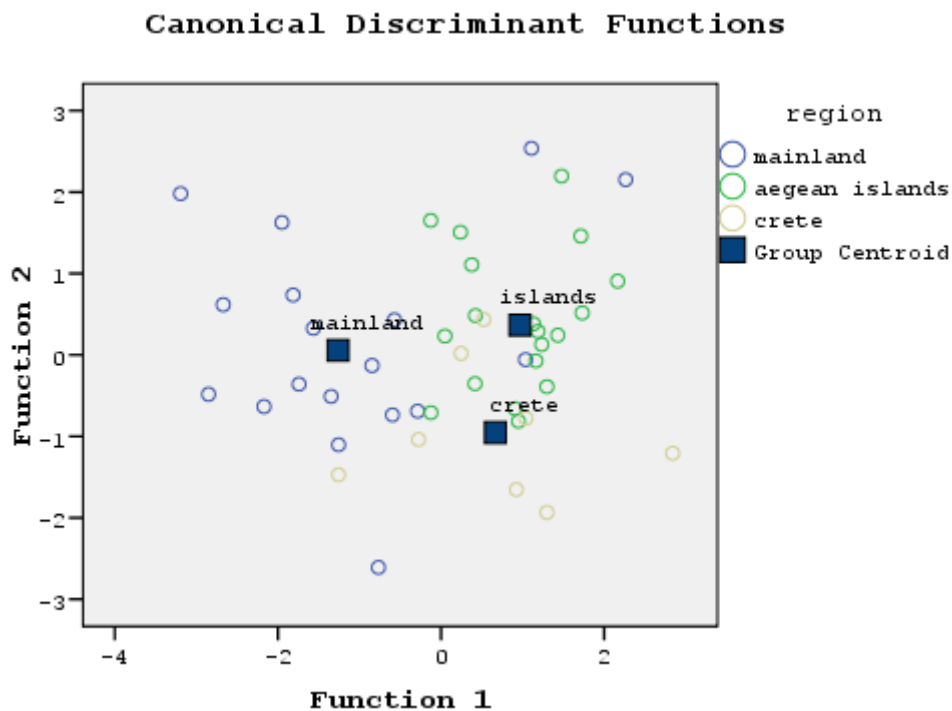


Figure 3. Plot of the first two discriminant functions by using skull measurements for male stone martens from mainland Greece, the Aegean Islands, and Crete.

Table 4. Classification* results % of male stone marten specimens in each sample area.

Sample area	Predicted group membership			Total
	Mainland Greece	Aegean Islands	Crete	
% Mainland Greece	68.4	15.8	15.8	100.0
Aegean Islands	5.3	63.2	31.6	100.0
Crete	12.5	37.5	50.0	100.0

*63.0% of cross-validated grouped cases correctly classified.

Table 5. Body measurements (mean ± SE) of female and male stone martens in three sample areas in Greece. Same letters (a, b, c) indicate that there were no differences between the sample areas. Bold letters indicate that mean values were significantly larger than the same measurement in the other area or areas.

Measurement	Mainland		Aegean Islands		Crete		P value	
	Female (n = 62)	Male (n = 57)	Female (n = 33)	Male (n = 36)	Female (n = 11)	Male (n = 16)	Female	Male
Body weight	1349.9^b ± 28.2	1589.2^b ± 28.3	1175.0 ^a ± 32.7	1455.1 ^a ± 33.1	1181.7 ^a ± 70.1	1491.8^{ab} ± 66.6	<0.001	0.013
Body length	38.57 ± 0.28	39.71 ± 0.28	38.59 ± 0.27	39.09 ± 0.22	38.01 ± 0.52	38.79 ± 0.33	0.710	0.056
Tail length	21.70^b ± 0.18	22.48^a ± 0.18	18.9 ^a ± 0.21	20.04 ^b ± 0.12	19.07 ^a ± 0.28	20.85 ^c ± 0.16	<0.001	<0.001
Ear length	2.89^b ± 0.04	3.19^b ± 0.06	2.50 ^a ± 0.07	2.76 ^a ± 0.06	2.64^{ab} ± 0.06	2.66 ^a ± 0.14	<0.001	<0.001
Body height	18.93^c ± 0.17	20.38^b ± 0.29	15.19 ^a ± 0.41	15.49 ^a ± 0.29	16.33 ^b ± 0.37	16.32 ^a ± 0.42	<0.001	<0.001

Table 6. Standardized coefficients of the first two discriminant functions.

Body size variables	DF1		DF2	
	Male	Female	Male	Female
Weight	-0.230	-0.128	-0.045	-0.039
Body length	0.148	-0.144	1.004	1.007
Tail	1.063	1.070	-0.164	-0.010
Eigenvalues	1.199	1.193	0.01	0.007
Variance explained %	99.2	99.4	0.8	0.6

validated grouped cases) of males and females respectively by sampling area (Table 7).

4. Discussion

Geographical variation in craniometrics of the stone marten has been reported in Europe, with an increase in body size from west to east (Reig, 1992). Results of the analyses performed on the means of the skull measurements showed a great overlap among stone martens from the mainland and insular areas (only 5 skull measurements in males and 3 in females were significantly different). In contrast, Delibes and Amores (1986) found that Ibiza stone martens

were significantly smaller than European ones in almost all compared skull measurements. In addition, De Marinis and Pandolfi (1995) found that two populations of stone martens from northwestern Italy and two from central-western Switzerland significantly differed, especially in the masticatory apparatus. Their results revealed a clear separation between Italian and Swiss stone marten skulls with 90.77% correct classification, indicating that morphometric variation exists between local populations and not only in a large geographic scale. The classification of male skulls in the three sampling areas showed that the cross-validated correct classification rate was relatively low

Canonical Discriminant Functions

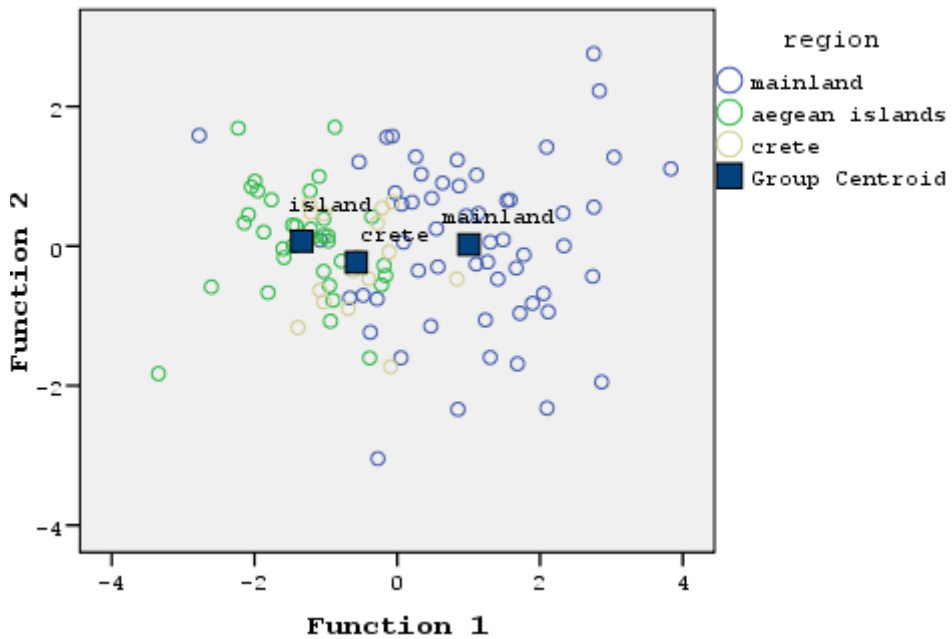


Figure 4. Plot of the first two discriminant functions by using body size variables for male stone martens from mainland Greece, the Aegean Islands, and Crete.

Canonical Discriminant Functions

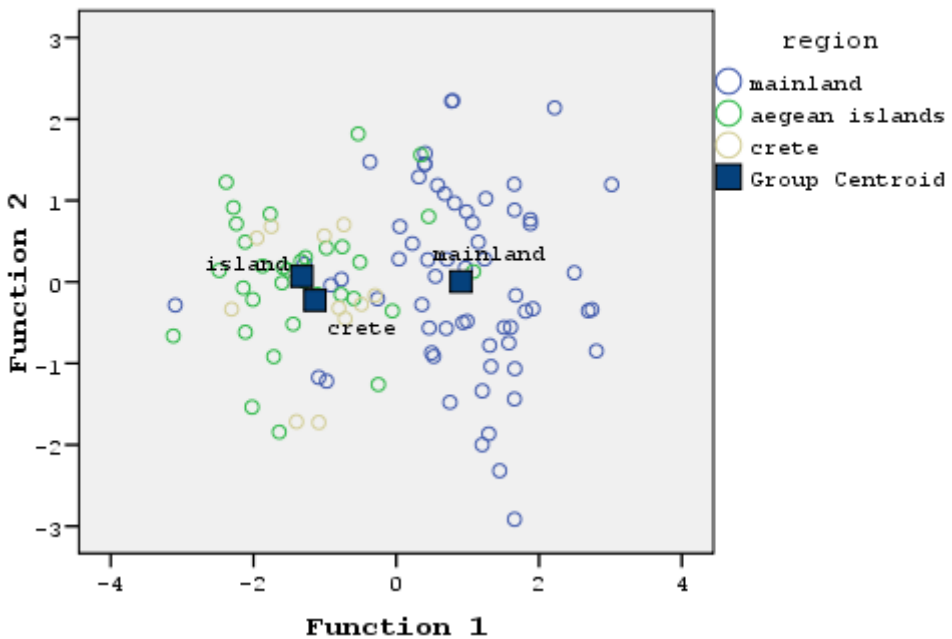


Figure 5. Plot of the first two discriminant functions by using body size variables for female stone martens from mainland Greece, the Aegean Islands, and Crete.

Table 7. Classification* results % of male and female stone marten specimens in each sampling area.

	Sample area	Predicted group membership						Total	
		Mainland Greece		Aegean Islands		Crete		Males	Females
		Males	Females	Males	Females	Males	Females		
%	Mainland Greece	73.7	87.1	5.3	4.8	21.1	8.1	100.0	100.0
	Aegean Islands	0.0	12.1	72.2	54.5	27.8	33.3	100.0	100.0
	Crete	6.3	0.0	25.0	45.5	68.8	54.5	100.0	100.0

*72.5% and 73.6% of cross-validated grouped cases correctly classified males and females, respectively.

(63%), and therefore the discrimination of skulls was not strong enough between mainland and insular individuals. In contrast, other studies showed up to 100% correct classification between mammal subspecies, such as foxes, tigers, and dolphins (Baker et al., 2002; Mazak and Groves, 2006; Oishi et al., 2010), and their differentiation was mainly due to differences in almost the same variables for both sexes. Although the use of the basic condyle length (Cb_L) is the most reliable characteristic to estimate the body size and is widely used in biogeography (Rausch, 1963; Ralls and Harvey, 1985; Ellison et al., 1993; Quin et al., 1996; Jones, 1997), in the present study, Cb_L was larger in males in the Aegean Islands and mainland than in Crete. Cb_L variation in individuals from the mainland and islands did not show or follow a specific geographic cline or pattern. Furthermore, the average Cb_L is consistent with the range of the measurements made by Yiğit et al. (1998) in stone martens from different localities in Turkey. Ashton et al. (2000) consider that in mustelids predator-prey models predominate over other selection factors to determine their size. A key factor is the availability and spatial distribution of prey within their distribution range (Meiri et al., 2007). The diet of the stone marten varies seasonally and spatially (Papakosta et al., 2014); thus it is difficult to compare the availability and quality of its prey among different areas. In addition, the larger CaT-L in males from Crete may be due to food nutrition, which can influence the development of various parts of the skull at an early age, and not due to the abundance of prey (Englund, 2006).

The classification results, based on body size measurements, showed higher rates (72.5% for males and 73.6% for females) than craniometrics, possibly due to body weight, which generally shows an endogenous variability (e.g., daily, seasonally, with reproductive conditions). Thus other measurements are proposed, such as skull and body length, as the most representative measurements of the size (Ralls and Harvey, 1985). In this study, skull length and body length did not significantly

differ among the three populations, whereas body weight varied considerably among populations. The resulting heavier stone martens from mainland Greece contradict Nagorsen's (1994) theory of largest body on islands, but Foster (1964) reported a reversal trend of the body size in the Mediterranean. Therefore, the degree of morphological differentiation on island populations probably depends on the isolation of the island. In addition, Gortazar et al. (2000) found that intraspecies body size can vary in relation to habitat change, even on a microgeographic scale. These relatively high classification results of body size are consistent with other authors' findings, which revealed an even higher intraspecies morphological variation in stone marten populations from different regions (De Marinis and Pandolfi, 1995) as well as in other mammal species (Gortazar et al., 2000; Lynch et al., 1996). In general, intraspecific morphological variation may be due to spatial ecological variations, evolutionary processes (such as the migratory history of the species (Masseti, 1995a)), and geographic isolation (De Marinis and Pandolfi, 1995); moreover, it may be habitat-related in a microgeographic scale (Gortazar et al., 2000).

The Mediterranean region has been subject to intense anthropogenic effects. Since prehistoric times, human settlement in the Mediterranean islands affected the endemic fauna with the introduction of modern mammals. Many Mediterranean islands were formed after the separation of parts from the mainland during geological processes and morphological changes that occurred 20 million years ago. Fossil remains of stone martens have only been reported from postglacial deposits in Europe, (Kurten, 1968; Anderson, 1970; Sala, 1992). It represents a Palaearctic species characteristic of the Irano-Turanian Region penetrating into the Mediterranean Region (Atallah, 1978). The island of Rhodes perhaps provides the oldest as-yet discovered findings of continental mustelids in island archaeological contexts. They are represented by the remains of a marten, presumed biogeographically to belong to a stone marten (Halstead and Jones, 1987).

Moreover, continental mustelids have also been reported from several archaeological sites on Crete (Masseti 1995a, 1995b). With the above assumptions, it is supported that many species arrived in the Mediterranean islands from the mainland through land corridors linking these regions. According to Malatesta (1980), Crete during the Pleistocene was connected with mainland Greece. Fossils from Peloponnese showed the presence of stone martens in the area since Middle Pleistocene (Tsoukala 1999). Today the most common carnivore in the Mediterranean islands is the stone marten, which is considered to have followed the human civilization introduced in Europe from the mainland of the Near East at the end of the Pleistocene or the early Oligocene (Kurten, 1968; Anderson, 1970; Masseti, 1995). Mustelids were imported was not only to provide food to prehistoric man, but may have also been utilized for their fur, as suggested by Grundbacher (1992).

In conclusion, the formation of Aegean Islands, the fossil records, and the importation of the species at the end of the Pleistocene support the assertion that the insular populations originate from the mainland, and that the resulting morphological variation between mainland

and insular stone martens is probably due to the intrinsic variation of individuals and does not demonstrate a strength presence of subspecies in the Aegean Islands. The resulting morphometric differences may be considered microevolutionary and habitat-related, probably due to selective pressures (e.g., lack of resources, the existence or not of competition). Furthermore, a genetic analysis of the species showed that the limited genetic distance of discovered haplotypes and the recovery of the same mitochondrial haplotypes at very distant sites do not favor the existence of separate *Martes foina* subspecies in the Aegean Islands (Papakosta et al., 2012). A further analysis of stone martens from the Mediterranean area, especially from coastal Turkey, is suggested for comparison and to give an insight to the migratory history of the species.

Acknowledgments

The author would like to thank the Hunting Confederation of Greece for their help in collecting samples. In addition, the author is thankful to Prof D Bakaloudis and Prof K Kitikidou for their useful comments and suggestions on a draft of the manuscript. The author declares that the experiments comply with Greek and EU laws.

References

- Abramov AV, Kranz A, Herrero J, Choudhury A, Maran T (2016). *Martes foina*. The IUCN Red List of Threatened Species 2016: e.T29672A45202514. <http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T29672A45202514.en>.
- Albayrak I, Özen A, Kitchener A (2008). A contribution to the age-class determination of *Martes foina* Erxleben, 1777 from Turkey (Mammalia: Carnivora). *Turk J Zool* 32: 147-153.
- Anderson E (1970). Quaternary evolution of the genus *Martes* (Carnivora, Mustelidae). *Acta Zool Fenn* 130: 1-133.
- Ashton KG, Tracy M, de Queiroz A (2000). Is Bergmann's rule valid for mammals? *Am Nat* 156: 390-415.
- Atallah S (1978). Mammals of the Eastern Mediterranean region: their ecology, systematics and zoogeographical relationships. *Saugterierk Mitt* 26: 1-50.
- Aung S, Ngim R, Lee S (1995). Evaluation of the laser scanner as a surface measuring tool and its accuracy compared with direct facial anthropometric measurements. *Bri J Plast Surg* 48: 551-558.
- Baker A, Adam N, Smith H, Pichler F (2002). Geographical variation in Hector's dolphin: recognition of new subspecies of *Cephalorhynchus hectori*. *J R Soc N Z* 32: 713-727.
- Bate DMA (1905). On the mammals of Crete. *Proc Zool Soc London* 2: 315-323.
- Delibes M, Amores F (1986). The stone marten *Martes foina* from Ibiza (Pitiusic, Balearic islands). *Misc Zool* 10: 335-345.
- de Marinis A, Pandolfi M (1995). Morphometric variation in stone marten *Martes foina* in Western Alps in relation to climate. *Hystrix* 7: 119-125.
- Douma-Petridou E (1984). Contribution to the knowledge of *Martes foina* Erxl. (Mammalia, Carnivora) from Achaia, northern Peloponnese Greece and rest southern Balkan Peninsula. *Mammalia* 48: 565-572.
- Ellison G, Taylor P, Nix H, Bronner G, McMahon J (1993). Climatic adaptation of body size among pouched mice (*Saccostomus campestris*, Cricetidae) in the southern African subregion. *Glob Ecol Biogeogr Lett* 3: 41-47.
- Englund J (2006). Cranial and skeleton size in red foxes, *Vulpes vulpes* in areas with large variation in food abundance. *Russ J Theriol* 5: 25-34.
- Festa E (1914). Escursioni Zoologiche del Dr. Enrico Festa nell' isola di Rodi. *Mammiferi Boll Mus Zool Anat Comp Univ Torino* 29: 1-29.
- Foster JB (1964). Evolution of mammals on islands. *Nature* 202: 234-235.
- Fuentes ER, Jaksic FM (1979). Latitudinal size variation of Chilean foxes: tests of alternative hypotheses. *Ecology* 60: 43-47.
- Genovesi P, Secchi M, Boitani L (1996). Diet of stone martens: an example of ecological flexibility. *J Zool* 238: 545-555.
- Gortázar C, Travaini A, Delibes M (2000). Habitat-related microgeographic body size variation in two Mediterranean populations of red fox (*Vulpes vulpes*). *J Zool* 250: 335-338.

- Grundbacher B (1992). Nachweis des Baummarters, *Martes martes* in der neolithischen Ufresiedlung von Twann sowie Ammerkungen zur osteometrischen Unterscheidung von *Martes martes* und *M. foina*. Z. Säugetierkunde 57: 201-210.
- Halstead P, Jones G (1987). Bioarchaeological remains from Kalythies cave, Rhodes. In: Sampson A, editor. The Neolithic Period in the Dodecanese. Athens, Greece: British School at Athens. pp. 135-152.
- Holmes T, Powell R (1994). Morphology, ecology and the evolution of sexual dimorphism in North American Martes. In: Buskirk S, Harestad A, Raphael M, Powell R, editors. Martens, Sables and Fishers: Biology and Conservation. Ithaca, NY, USA: Cornell University Press, pp. 72-84.
- Jones M (1997). Character displacement in Australian dasyurid carnivores: size relationships and prey size patterns. Ecology 78: 2569-2587.
- King CM (1991). Body size-prey size relationships in European stoats *Mustela erminea*: a test case. Holarct Ecol 14: 173-185.
- Kryštufek B (2004a). The Cretan stone marten *Martes foina bunites*. Small Carniv Conserv 30: 2-4.
- Kryštufek B (2004b). The stone marten *Martes foina milleri* on the island of Rhodes. Small Carniv Conserv 31: 6-8.
- Kurten B (1968). Pleistocene Mammals of Europe. London, UK: Weidenfeld and Nicolson.
- Lynch J, Conroy A, Kitchener D, Jefferies D, Hayden T (1996). Variation in cranial form and sexual dimorphism among five European populations of the otter (*Lutra lutra*). J Zool 238: 81-96.
- Malatesta A (1980). Dwarf deer and other late Pleistocene fauna of the Simonelli Cave in Crete. Accad Naz Lincei Quad 249: 1-97.
- Masseti M (1995a). Quaternary biogeography of the Mustelidae family on the Mediterranean islands. Hystrix 7: 17-34.
- Masseti M (1995b). Presence and distribution of the Stone marten, *Martes foina* Erxleben, 1777, on the island of Crete (Greece). Hystrix 7: 73-78.
- Mazák JH, Groves CP (2006). A taxonomic revision of the tigers (*Panthera tigris*) of Southeast Asia. Mamm Boil 71: 268-287.
- McDonald R, King C (2000). Biology of mustelids: reviews and future directions. Mammal Rev 30: 145-146.
- Meiri S, Yom-Tov Y, Geffen E (2007). What determines conformity to Bergmann's rule? Global Ecol Biogeogr 16: 788-794.
- Nagorsen D (1994). Body weight variation among insular and mainland American martens. In: Buskirk S, Harestad A, Raphael M, Powell R, editors. Martens, Sables and Fishers: Biology and Conservation. Ithaca, NY, USA: Cornell University Press, pp. 72-84.
- Oishi T, Uruguchi K, Abramov A, Masuda R (2010) Geographical variations of the skull in the red fox *Vulpes Vulpes* on the Japanese islands: an exception to Bergmann's rule. Zool Sc 27: 939-945.
- Papakosta M, Andreadou M, Tsoupas A, Karaiskou N, Bakaloudis D, Chatzinikos E, Sakoulis A, Triadafyllidis A, Vlachos C (2012). Genetic analysis of stone marten (*Martes foina*) Greek populations. In: Legakis A, Georgiadis C, Pafilis P, editors. Abstracts of the International Congress on the Zoogeography, Ecology and Evolution of Southeastern Europe and the Eastern Mediterranean; 18-22 June 2012; Athens, Greece: Hellenic Zoological Society, p. 230.
- Papakosta M, Kitikidou K, Bakaloudis D, Vlachos C (2014). Dietary variation of the stone marten (*Martes foina*): a meta-analysis approach. Wildl Biol Pract 10: 85-101.
- Quin D, Smith A, Norton T (1996). Ecogeographic variation in size and sexual dimorphism in sugar gliders and squirrel gliders (Marsupialia: Petauridae). Austr J Zool 44: 19-45.
- Ragni B, Masseti M, Roussos T, Belardinelli A, Cicconi P (1999). The carnivores of the island of Crete, Greece. Contributions to the Zoogeography and Ecology of the Eastern Mediterranean Region 1: 117-123.
- Ralls K, Harvey P (1985). Geographic variation in size and sexual dimorphism of North American weasels. Biol J Linn Soc 25: 119-167.
- Rausch RL (1963). Geographic variation in size in North American brown bears, *Ursus arctos*, as indicated by condylobasal length. Can J Zool 41: 33-45.
- Reig S (1992). Geographic variation in pine marten (*Martes martes*) and beech marten (*Martes foina*) in Europe. J Mammal 73: 744-769.
- Rice WR (1989). Analyzing tables of statistical tests. Evolution 43: 223-225.
- Rosatte RC, Power MJ, MacInnes CD (1991). Ecology of urban skunks, raccoons, and foxes in metropolitan Toronto. In: Adams LW, Leedy DL, editors. Wildlife Conservation in Metropolitan Environments. Columbia, MD, USA: National Institute for Urban Wildlife, pp. 31-38.
- Sala B (1992). I mammiferi del Quaternario italiano. In: I segnidel tempo. Memoria delle origini ed icone del primordiale. Liceo Ginnasio "G. Prati", Trento, pp. 209-227.
- Serafini P, Lovari S (1993). Food habits and trophic niche overlap of the red fox and the stone marten in a Mediterranean rural area. Acta Theriol 38: 233-244.
- Sholts SB, Flores L, Walker P, Warmlander SK (2011). Comparison of coordinate measurement precision of different landmark types on human crania using a 3D laser scanner and a 3D digitiser: Implications for applications of digital morphometrics. Intern J Osteoarchaeol 21: 535-543.
- Tsoukala E (1999). Quaternary large mammals from the Apidima Caves (Lakonia, S Peloponnese, Greece). Beitr Palaont 24: 207-229.
- Yiğit N, Colak E, Sozen M (1998). Contribution to the taxonomy, distribution and karyology of *Martes foina* (Erxleben, 1777) (Mammalia: Carnivora) in Turkey. Turk J Zool 22: 297-301.
- Zar JH (1996). Biostatistical Analysis. 3rd ed. London, UK: Prentice Hall.