Hittite Journal of Science and Engineering, 2019, 6 (2) 131-136
ISSN NUMBER: 2148-4171
DOI: 10.17350/HJSE19030000138

Taxonomic Status of Water Vole, (Arvicola Amphibius Linneaus, 1758) in Western Anatolia

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ABSTRACT

A total of 116 specimens of the genus Arvicola were collected from western part of Turkey (Western part of Anatolia and Turkish Thrace) and examined based on geometric morphometrics and traditional morphometrics. Morphometrical analyses showed that A. amphibius populations in western part of Turkey are highly differentiated as Anatolian and Thrace populations. Depend on morphometrical differentiation, we conclude that these two populations, classified within two subspecies; Arvicola amphibius persicus and Arvicola amphibius cerncavskii respectively.

Article History:
Received: 2019/03/16
Accepted: 2019/06/27
Online: 2019/06/30

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Keywords:
Arvicola; Geometric morphometrics; Morphology; Thrace; Anatolia; Taxonomy.

INTRODUCTION

Over the last few decades, many studies have done to clarify the taxonomy of water voles (genus Arvicola Lacépede, 1799). Recent studies showed that water voles divided into three species; A. sapidus (Miller, 1908) , A. amphibius (Linnaeus, 1758) (formerly known as A. terrestris) and A. scherman (Musser and Carleton, 2005). The first records of water vole (A. amphibious) from the Turkey reported by Steiner and Vauk (1966) around Lake Beyşehir.

Depend on morphological and biometrical features, three water vole subspecies identified in Turkey; Arvicola amphibius persicus (Anatolia), Arvicola amphibius hintoni (Southeastern Anatolia Region), Arvicola amphibius cernjavskii (Thrace) (Mursaloğlu, 1975). amphibius comprises two ecological types which are aquatic and fossorial forms, each with different living habits and these ecotypes are often morphologically distinct (Meylan, 1977). And also recent studies lowerline that, water voles are characterized by an extraordinary morphological and ecological plasticity (Castiglia et al., 2016). Basically, geometric morphometrics allow to compare morphological objects by their shapes which can be described as the study of biological shapes. Traditional morphometrics has been quite a useful means in morphometrics for long years (Zelditch et al., 2004). Also, it has the most common use in morphometrics, and it is based on direct measurements and then comparison.

Therefore, usage of morphological methods may highly informative to obtain taxonomical situation of water vole that distributed in western part of Anatolia. Moreover, a biogeographic comparison allows the identification of the specific morphological response of water vole to the different environments.

In addition to that, our findings may be enlightening for further studies on population genetics and evolution of water vole because of the study area's biogeographic importance for Europe and Middle East. Furthermore, climate change and drying of inland water highly effect on genetic structure of this species therefore water vole populations can be a good model to investigate and contribute to those current problems.

Consequently, this study aimed to identify the patterns of morphological differentiations to better lowerstanding of taxonomy of water vole subspecies along the Turkish Thrace and Western part of Anatolia.

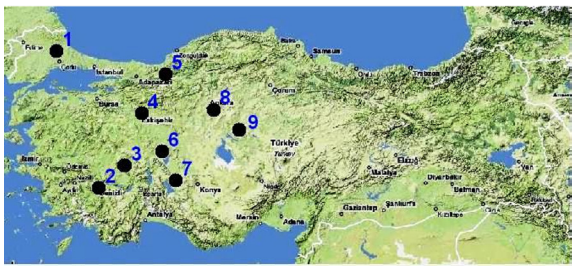

Figure 1. Localization of the sampling localities of water vole considered in the present study (1. Kırklareli , 2. Denizli, 3. Uşak, 4. Eskişehir, 5. Bolu, 6. Eber Gölü (*Çay*, Afyon), 7. Beyşehir (Konya) 8. Ankara, 9. Kırşehir)

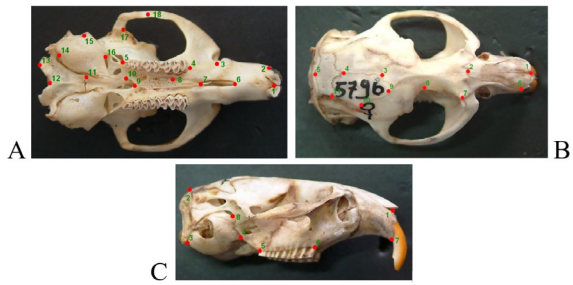

Figure 2. Landmarks used to capture skull shape on the water vole; Dorsal (A), ventral (B), lateral (C)

MATERIALS AND METHODS

Water voles were collected from 9 localities Western part of Anatolia between 2004-2007 (Fig. 1). Skulls of 85 adult individuals of two subspecies were examined.

Thrace samples were collected from Kırklareli at around 41° 67' N and 27° 07' E associated with temperate conditions. Anatolian samples were collected from western part of Anatolia vary at 40° 81' N and 32° 83' E and 38° 53' N and 28° 64' E (Table 1).

The skull images were taken with Leica MZ 16 stereomicroscope. Photographs were first input to TpsUtil1.34 and then 2D coordinates of each landmark were digitized using the Tps-Dig1.40 (Rohlf, 2004). The landmark configurations were superimposed to the same reference form by generalized least squares (Rohlf, 1999) in Morpheus (Slice, 2002).

Geometric morphometric data consisted of four sets; one referring to 11 landmarks on the dorsal side (Fig. 2A), 18 landmarks on the ventral side (Fig. 2B) and the other to 8 landmarks on the lateral side of the skull (Fig. 2C).

Depend on their close geographic position, some localities are combined and then 6 group defined; trak (Thrace), beys (Beyşehir), deus (Denizli-Uşak), abes (Ankara-Bolu-Eskişehir), kirs (Kırşehir), eber (Eber) (Table 2.).

4 external and 35 internal characters are measured. Table 2 shows that average measurements of morphometrical characters, minimum, maximum and standard deviations of Anatolian populations of Arvicola terrestris persicus(Table 3).

4 external and 35 internal morphometric characters are measured. Table 2 shows that average measurements of morphometrical characters, minimum, maximum and standard deviations of Thrace populations of Arvicola terrestris cernjavskii.

All statistical analyses to identify shape variations of water voles were performed using the SPSS 13.0 (SPSS, 2004).

Table 1. Trapping localities of water vole with per coordinates

Species	*Locality*	*Latitude*	*Longitude*
Arvicola terrestris persicus	*Kırşehir – Stream Kılıçözü*	*39.130926*	*34.151859*
Arvicola terrestris persicus	*Kırşehir – 12 km*	*39.167069*	*34.145164*
Arvicola terrestris persicus	*Kırşehir – 10 km*	*39.165871*	*34.145508*
Arvicola terrestris persicus	*Lake Seyfe*	*39.199802*	*34.418106*
Arvicola terrestris persicus	*Ankara –Ayaş*	*40.086379*	*32.118230*
Arvicola terrestris persicus	*Bolu –Yeniçağa*	*40.773327*	*32.030725*
Arvicola terrestris persicus	*Bolu –Eskiçağa*	*40.819168*	*32.036862*
Arvicola terrestris persicus	*Kahramanmaraş –Göksun*	*38.018886*	*36.486969*
Arvicola terrestris persicus	*Afyon – Lake Eber*	*38.668411*	*31.177356*
Arvicola terrestris persicus	*Konya –Beyşehir*	*37.682450*	*31.747616*
Arvicola terrestris persicus	*Denizli – Çivril*	*38.301485*	*29.741691*
Arvicola terrestris persicus	*Denizli – Çivril Yuvaköy*	*38.301485*	*29.741691*
Arvicola terrestris persicus	*Uşak – Kula*	*38.542283*	*28.651150*
Arvicola terrestris persicus	*Uşak – Yenişehir*	*38.676711*	*29.033657*
Arvicola terrestris persicus	*Eskişehir – Gülçayır*	*39.248721*	*31.399511*
Arvicola terrestris cerjavskii	*Kırklareli – İnece*	*41.704660*	*27.063521*

Table 2. External and internal lineer measurement characters of *Arvicola terrestris persicus*

	Measurements Characters	N	avg.	Min.	Max.	SS (+/-)
1.	Total lenght	79	305,20	213,00	378,00	34,23
2.	Tail	79	125,96	81,00	152,00	14,39
3.	Hind leg	79	36,78	27,00	42,00	2,47
4.	Ear length	79	16,88	9,00	21,00	2,62
5.	Weight	79	142,14	59,00	237,00	38,09
6.	Zygomatic width	79	23,05	19,35	25,94	1,62
7.	Least breadth of skull	79	4,85	3,96	6,10	0,37
8.	Condylobasale length	79	37,63	31,26	41,48	2,34
9.	Condylobasale length	79	39,86	33,59	43,80	2,31
10.	Occipitonasale length	79	38,11	19,55	42,71	3,67
11.	Basale length	79	36,39	29,26	40,17	2,14
12.	Nasal length	79	10,92	8,72	12,70	0,98
13.	Nasal width	79	4,77	3,65	6,99	0,64
14.	Perietal suture uzunluğu	79	7,96	6,16	9,04	0,56
15.	Face area lenght	79	24,02	10,16	34,01	2,49
16.	Brain area lenght	79	15,47	11,09	17,43	1,12
17.	Mastoid width	79	11,00	9,11	12,48	0,70
18.	Bulla tympanica length	79	13,10	11,61	14,80	0,68
19.	Bulla tympanica width	79	11,88	9,82	70,93	6,81
20.	Occipitale width	79	15,65	12,42	17,48	1,06
21.	Brain capsule width	79	14,57	12,60	15,65	0,59
22.	Diestama lenght	79	13,19	10,34	15,54	1,12
23.	Palatal lenght	79	21,69	17,91	24,09	1,47
24.	Insisiva length	79	6,68	4,46	9,76	0,74
25.	Bulla tympanica length	79	9,88	7,66	11,17	0,54
26.	Bulla tympanica width	79	7,04	6,12	8,36	0,35
27.	Mandibulae length	79	26,29	22,21	29,15	1,64
28.	Mandibulae height	79	6,45	5,16	8,84	0,57
29.	Upper molar alveoli length	79	9,13	7,72	10,44	0,62
30.	Upper molar length	79	10,13	9,02	11,90	0,61
31.	Length of lower teeth alveoli	79	9,24	7,82	10,55	0,64
32.	Lower molar length	79	9,98	8,54	11,68	0,58
33.	Coronoid prossess height	79	13,99	11,45	16,09	1,05
34.	First upper molar length M1	79	8,59	7,63	10,26	0,62
35.	Second upper molar length M2	79	6,25	5,00	7,36	0,55
36.	Third upper molar length M3	79	6,22	3,16	7,63	0,68
37.	First lower molar length M1	79	9,26	7,63	11,05	0,73
38.	Second lower molar length M2	79	6,00	5,00	8,94	0,59
39.	Third lower molar length M3	79	5,95	4,73	8,94	0,63

N: number of sample, avg: avarage, min: minimum, max: maksimum, SS: Standart deviation

Table 3. External and internal lineer measurement characters of *Arvicola terrestris cernjavskii*

	Measurements Characters	N	avg.	Min.	Max.	SS (+/-)
1.	Total lenght	6	314,67	297,00	340,00	16,79
2.	Tail	6	121,17	104,00	130,00	9,43
3.	Hind leg	6	34,50	33,00	36,00	1,05
4.	Ear length	6	17,17	14,00	19,00	1,83
5.	Weight	6	173,50	152,00	193,00	16,28
6.	Zygomatic width	6	23,45	22,95	24,54	0,68
7.	Least breadth of skull	6	4,77	4,52	5,04	0,17
8.	Condylobasale length	6	37,81	36,15	39,76	1,51
9.	Condylobasale length	6	39,73	38,27	42,06	1,61
10.	Occipitonasale length	6	38,83	37,41	41,45	1,67
11.	Basale length	6	32,59	17,65	37,91	8,41
12.	Nasal length	6	10,55	10,08	10,82	0,35
13.	Nasal width	6	4,51	4,11	5,07	0,40
14.	Perietal suture uzunluğu	6	7,97	7,07	8,88	0,69
15.	Face area lenght	6	24,28	23,34	26,28	1,17
16.	Brain area lenght	6	15,60	15,06	16,14	0,52
17.	Mastoid width	6	11,71	11,11	12,20	0,45
18.	Bulla tympanica length	6	12,69	12,08	13,12	0,40
19.	Bulla tympanica width	6	11,08	10,72	11,36	0,26
20.	Occipitale width	6	15,77	15,18	16,47	0,60
21.	Brain capsule width	6	14,80	14,44	15,42	0,41
22.	Diestama lenght	6	13,23	12,08	14,35	0,92
23.	Palatal lenght	6	21,65	20,29	23,73	1,23
24.	İnsisiva length	6	6,51	5,81	7,01	0,47
25.	Bulla tympanica length	6	9,78	9,16	10,62	0,53
26.	Bulla tympanica width	6	7,02	6,90	7,12	0,10
27.	Mandibulae length	6	26,42	24,76	28,00	1,14
28.	Mandibulae height	6	6,46	6,22	6,63	0,14
29.	Upper molar alveoli length	6	9,07	8,71	9,55	0,37
30.	Upper molar length		10,11	9,56	10,81	0,47
31.	Length of lower teeth alveoli	6	9,26	8,92	9,94	0,40
32.	Lower molar length		10,16	9,61	10,93	0,61
33.	Coronoid prossess height		13,27	11,86	14,22	0,93
34.	First upper molar length M1	6	8,77	8,15	9,47	0,52
35.	Second upper molar length M2	6	6,49	6,31	6,84	0,21
36.	Third upper molar length M3	6	6,00	5,79	6,05	0,12
37.	First lower molar length M1	6	8,90	8,15	10,52	0,92
38.	Second lower molar length M2	6	5,74	5,26	6,31	0,39
39.	Third lower molar length M3	6	5,84	5,52	6,31	0,43

N: number of sample, avg: avarage, min: minimum, max: maksimum, SS: Standart deviation

RESULTS

Based on shape analysis of dorsal view of water vole UPGMA dendogram (Fig.3A) we find no significant differentiation basis for Turkish Thrace and Western part of Anatolia populations.

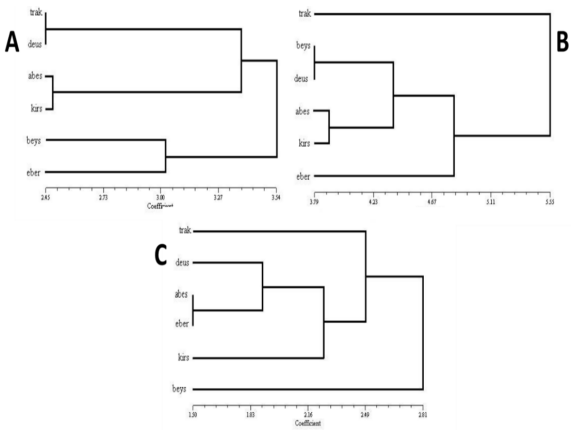

Figure 3. Dorsal (A), ventral (B) and lateral (C) differentiation between localities based on UPGMA by using landmark geometric morphometric (Groups; trak: Thrace, beys: Beyşehir, deus: Denizli-Uşak, abes: Ankara-Bolu-Eskişehir, kirs: Kırşehir, eber: Eber)

Our UPGMA dendogram results indicate clear confirmation of the subspecies-level status of Arvicola amphibius persicus (Anatolia) and Arvicola amphibius cernjavskii (Thrace) depend on ventral and lateral view of water vole skull (Fig. 3B, C). Fig. 3C also indicates that Beysehir population is different from all other populations, and Thrace population is much closer to the other populations. Comparing to Arvicola terrestris subspecies populations; tail, ear, condilobasale lenght, basale lenght, nasal lenght, parietal sutur lenght, mastoid, width, diestama lenght, damak lenght, bulla tympanica lenght, bulla tympanica width, mandibul lenght, Mandibulae height, under molar alveoli length, under molar length, coronoid prossess height, under M2, under M3 ve upper M2 measurements are quite different within 2 subspecies.

Comprasion of Arvicola terrestris populations depend on measurements of external and internal characters shown on Fig. 4.

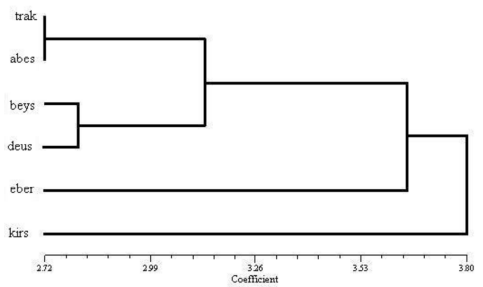

Figure 4. UPGMA dendogram that shows morphometrical relations of *Arvicola terrestris* populations depend on external and internal measurements

DISCUSSION

The shape of organs or structures are important in the interaction between the organism and its environment. It is quite common to associate taxonomic differentiation with morphological divergence (Renaud and Michaux, 2003; Rohlf, 1990).

Arvicola subspecies; Arvicola amphibius persicus, Arvicola amphibius armenius and Arvicola amphibius hintoni which are recorded from Anatolia and those subspecies are investigated in a previous study (Mursaloğlu, 1975) and only persicus and hintoni accepted as a subspecies because of differentiation of populations depend on morphological and biometrical features. And armenius noticed as a synonym of percicus. Concequently Mursaloğlu (1975) defined Arvicola amphibius cernjavskii from Turkish Thrace and Arvicola amphibius persicus from Central Anatolia. Again, this review stops more than 40 years ago. For example, the data and statements presented by Krystufek & Vohralik (2005) are not considered.

In this study, in Anatolian populations; average head-body length 179 mm, tail lenght 125 mm, hind lenght 27-42 mm, condylobasale lenght 39,26-41,48 mm, in Thrace populations; average head-body length 193,5 mm, tail lenght 121.17 mm, hind lenght 33-36 mm, condylobasal lenght 36,15-39,76 mm are measured. Depend on these measurements except tail measurements of Anatolian populations are consistent with Miller (1912) and the other differences is head and body length of Thrace populations.

Mursaloğlu (1975) recorded Arvicola terrestris cernjavskii from Trakya, and Arvicola terrestris persicus subspecies from Central Anatolia. According to Mursaloğlu (1975), the average and minimum - maximum measurements of 11 Arvicola terrestris persicus samples obtained from Central Anatolia; the length of the whole length is 297.5 mm (229 - 318), the head - body length is 180.2 mm (115 - 200) and the weight is 170.6 g (130 - 209). Measurements of Western Anatolian Arvicola terrestris persicus specimens examined in this study compared with the samples obtained from Central Anatolia by Mursaloglu, whole lenght, head-body lenght and weight measurements were found to be smaller. These average whole lenght values are greater than the maximum value given by the researcher for the whole length (318 mm) and head - body length (200 mm). In addition, the mean value of the weight measurements of Arvicola terrestris persicus subspecies samples of Mursaloğlu (1975) is 170.6 gr. The average weight of the samples collected in this study is larger.

In our study, it is first time we analysed geometric morphometrics on Turkish Arvicola samples distributed on

western part of Anatolia. A total of 37 landmarks on dorsal, ventral and lateral view of the skull were used to identified differentiation level of Arvicola populations in western part of Anatolia. We found any evidence of differentiation between Thrace and Anatolia populations according to dorsal view of water vole skull. However ventral and lateral view of water vole skull strongly support that Turkish Thrace and Western part of Anatolia water vole populations are highly differentiated two subspecies of water vole Arvicola amphibius persicus and Arvicola amphibius cerncavskii distributed through Western part of Turkey by using landmark based geometric morphometrics.

Thus, ventral and lateral view of skull is quite efficient to determine intraspecies variations of water vole by using geometric morphometrics. On the other hand, dorsal view of water vole skull is not informative to explain intraspecific variations of water vole subspecies throughout Western part of Turkey.

In addition to these, during field study, we observed that the distribution area of Arvicola amphibius is highly limited by water pollution, anthropogenic impact and climate change.

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