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The importance of shape analysis of the first upper molar in the separation of two subspecies of the Hazel dormouse (*Muscardinus avellanarius* (Linnaeus, 1758)) in Northern Anatolia

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Abstract: Morphological features are important for intraspecific and interspecific variation. Teeth are important taxonomical characteristics because they can differ according to diet. Shape analysis of the first upper molar (M1) was used to determine geographical variations and effects of ecological changes on the population structure of Hazel dormice (*Muscardinus avellanarius*) living in Turkey. Both outline and landmark analysis, as well as a canonical variates analysis, showed significant differences in teeth shape between populations. With this technique, we separated out two subspecies: *M. a. trapezius and M. a. abanticus.*

Key words: Anatolia, Fourier analysis, geometric morphometrics, hazel dormouse, *Muscardinus avellanarius*

1. Introduction

The hazel dormouse, *Muscardinus avellanarius*, is distributed throughout Europe and northern parts of Turkey—except Thrace (Kıvanç, 1983)—and ranges from Italy to Russia (Wilson and Reeder, 2005; Hutterer et al., 2016) (Figure 1a). In Turkey, this species is arboreal and rare, living in an area extending from Bursa (Uludağ) to Trabzon, covered with deciduous forests including mainly hazelnut trees (*Corylus* sp.) (Yiğit et al., 2006). Within these ranges, they prefer habitats with high biodiversity for feeding, nesting, and avoiding predators (Juškaitis, 2008). They rarely descend to the ground from the bushes where they live, unless it is necessary—for example when hibernating (Bright and Morris, 1991; Capizzi et al., 2002; Morris, 2003; Bright et al., 2006). Sometimes habitats become fragmented, causing loss of the species range, decreasing migration of the species, and increasing predation risk (Amori, 1993; Mortelliti et al., 2010, 2014; Goodwin et al., 2018).

Throughout Turkey, multiple subspecies of *M. avellanarius* have been identified. *M. avellanarius*, specifically, was first recorded by Nehring (1903) from İstanbul (Ümraniye), in the Northwestern region of Turkey. Miller (1908) assigned the specimens from an Eastern region, Trabzon (Coşandere) as *M. trapezius*. Then, Ellerman (1948) evaluated *M. trapezius* as a subspecies of *M. avellanarius*, naming it *M. a. trapezius*. Later, Kıvanç (1983) recorded *M. avellanarius* in Trabzon (Yomra) and Ordu (Ulubey)—the Northeastern region—and also in Bolu (including Abant-Soğuksu, Yenice, Köseköy, Yığılca) and Bursa (Yenikonak)—the Northwestern region. Kıvanç (1983) described the specimens from the specific region of Bolu, Abant-Soğuksu as a new subspecies, *M. a. abanticus*. This limited data suggests that *M. a. trapezius* is found in the Northeastern region, while *M. a. abanticus* is found in the Northwestern region. However, this data is insufficient to make this conclusion. Karyological aspects would help further identify these groups, but they have only been determined for *M. a. trapezius* by Doğramacı and Kefelioğlu (1992) and Şekeroğlu et al. (2011), while the karyological aspects of *M. a. abanticus* remain limited. Overall, these studies indicate that more information is necessary to justify the taxonomic status at the intrapopulation level of *M. avellanarius* in Turkey.

One new method to determine the taxonomic status of animals at the intrapopulation level is with geometric morphometric analysis of their cranial bone and teeth. Geometric morphometric analysis often represents geographical and ecological variations (Caumul and Polly, 2005; Yamada et al., 2018). For example, Caumul and Polly (2005) investigated changes in skull shape due to environmental factors in marmots (Rodentia). In the

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analysis of the molars, they found significant differences in the intraspecies and interspecies populations of marmots. Yamada et al. (2018) morphologically evaluated the geographical differences of pig (*Sus scrofa*) populations (Artiodactyla) and analysed the lower molars as morphological characters, finding significant differences between subspecies. Dentition patterns can be used from both fossil and actual specimens (Dayan et al., 2002). They reflect the peculiarity of divergent lineages and reflect ecological changes (Cardini, 2003; Renaud and Michaux, 2007; Ledevin et al., 2010) because adaptation to ecological niches can be observed as morphological features leading to taxonomic diversifications (Heard and Hauser, 1995; Kaya and Kaymakçı, 2013). Thus, geometric morphometrics techniques are a tool to analyse such effects of ecological changes on the morphological aspects of populations (Echeverry et al., 2020; Parés-Casanova et al., 2020).The most important morphological aspects to investigate are patterns of molars. Shape analysis, specifically, may reflect changes in dentition to food habits. For example, the cusp pattern on the occlusal surface must be adapted to break food up into smaller parts during chewing (Kaya and Kaymakçı, 2013). Moreover, molars are useful in distinguishing geographic populations because they show less ecophenotypic variation (Caumul and Polly, 2005). Also, the first molars often give more significant results, since the third molar shows extreme variation among the three molars, and the second molar is stuck between the first and third (Renaud et al., 1996; Renaud, 2005; Renaud and Michaux, 2007). There are also studies showing that climatic changes cause differentiation in tooth morphology, in this context, the expansion of open and step areas resulted in the evolution of animals with hypsodont teeth (Cerling et al., 1997; Fortelius et al., 2002; Tapaltsyan et al., 2015). Morphological characters may be directly related to the ecological characteristics of each taxon, such as habitat or diet (Auffray et al., 2009). Some researchers have shown that there is an interesting relationship between tooth characteristics and grazing diets in rodents with traditional morphometrics methodologies in lateral view (hypsodont) or occlusal modelling (Williams and Kay, 2001). Notably, the actual composition of the diet is determined by seasonal availability (Freudenthal et al., 2014); thus, diet can change throughout the seasons. Today geometric morphometrics methodologies are of great interest because they enable researchers to quantify variations in shape and size to develop a morphospace that facilitates their ecological and evolutionary implications (Renaud et al., 1996; Michaux et al., 2007; Samuels, 2009; Ledevin et al., 2010). For example, in a study with fossils of *Apodemus*, *Maxomys*, *Mus*, etc., the geometric morphometrics comparison of the first upper molar scratches suggested ecological preferences in the diet based on tooth morphology, and these studies, along with phylogenetic studies, helped to map the evolutionary history of feeding habits (Gomez Cano et al., 2013). Moreover, in the Northwest and Northeast Anatolia region, the accumulation of the ecological changes from the past to the present within *Glis* and *Apodemus* was established by geometric morphometric techniques (Helvacı et al., 2012; Helvacı and Çolak, 2021). For example, Helvacı et al. (2012) found that *Glis glis* populations differ in first upper molars due to geographical and anthropogenic factors.

M. avellanarius distributed in the North and Northwest Anatolia region also has a long evolutionary history (Kaya and Kaymakçı, 2013). Today, North and Northwest Anatolian regions are one of the regions most affected by geological and tectonic events as well as Pleistocene climatic changes during a period that lasted from the late Miocene to the present day (Popov et al., 2004, 2006; Dubey et al., 2006; Okay and Topuz, 2017). However, the subspecies specification of the *M. avellanarius* is problematic. In this context, we aim in this study to present shape variations of the first upper molar of *M. avellanarius*, adding knowledge about this species to the literature. Considering the impact of ecological factors on morphological variations, we investigated whether there are morphological variations between the first upper molars of *M. avellanarius* living in rare populations.

The aim of this study was to evaluate the importance of the first upper molar in the differentiation of the subspecies of *M. avellanarius*.

2. Materials and methods

This study determined the shape analysis of the first upper molars (M1) from 56 specimens of the hazel dormouse (*Muscardinus avellanarius*). A total of 33 specimens from collections and 23 live specimens were taken from Ankara University-Faculty of Science-Vertebrate Research Laboratory and Ankara University Mammalian Research Collection (AUMAC), respectively. Only adult specimens were used, and they were trapped between 1979 and 2017 in six localities in Northern Anatolia (Figure 1b).

Each of the specimen's skull images was photographed with a stereomicroscope-connected camera. For discriminant analysis, canonical variate analysis was done by Mystat 12.

2.1. Outline analysis

We sampled 64 points as equal along the occlusal surface of the left first upper molar using TpsDig. The start point was digitized at the junction point between the premolar and the first upper molar (Figure 2). Using the first nine harmonics for the M1, an elliptic Fourier analysis was applied to the M1 outlines (Figure 3).

2.2. Landmark analysis

Nine landmarks were digitized to the left first upper molar using by TpsDig. Number 1 and 2 are junction points

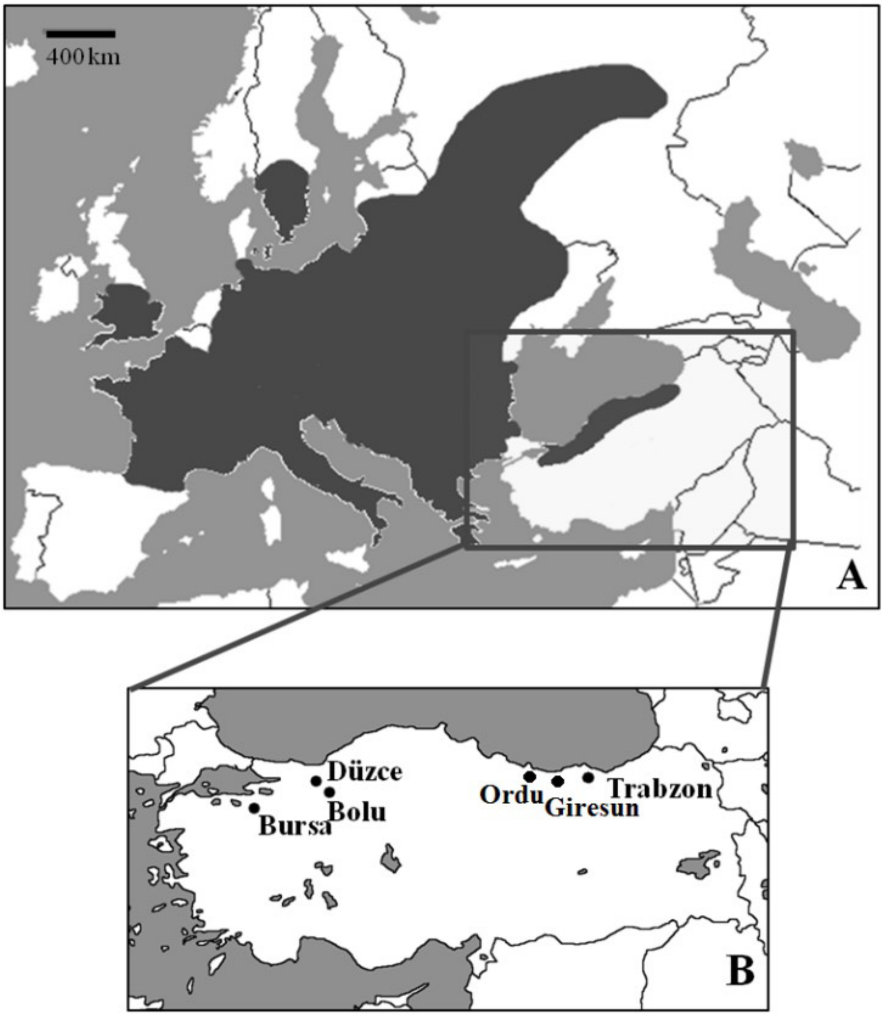

Figure 1. Worldwide distribution of *Muscardinus avellanarius* (a) and trapped localities in Northern Anatolia, Turkey (b) [Number of specimens: in the West; Bolu = 23, Bursa = 3, Düzce = 6, and in the East; Giresun = 4, Ordu = 6, Trabzon = 14].

between the premolar and the first upper molar, number 3, 4, 5, and 6 are the maximum curvature of the outline, number 7 and 8 are junction points between the first upper molar and the second upper molar, number 9 is the maximum cavity of the outline along the lingual side (Figure 4). All of the landmarks were superimposed using MorphoJ.

3. Results

Shape analysis of the first upper molar of *M. avellanarius* populations displayed significant differences. The canonical variates analysis showed two canonical values for 76% of the total variation of the samples (CA1: 41%, CA2: 35%, $p < 0.01$). Figure 5 exhibited the morphological variations of the first upper molar at the first two canonical axes.

Bolu, Bursa, and Giresun populations displayed positive values on the CA1 axes, whereas Bursa, Bolu, Düzce, and Trabzon populations showed positive values on the CA2 axes. The Bursa population tended to show positive values along both CA1 and CA2 axes.

The canonical variates analysis showed two canonical values for 70% of the total variation of the samples (CA1: 42%, CA2: 28%, $p < 0.01$) for landmark analysis. Figure 6 shows the morphological variations of the first upper molar at the first two canonical axes.

Ordu, Giresun, and Trabzon populations displayed positive values on the CA1 axes, whereas Bursa and Trabzon populations showed positive values on the CA2 axes. The Düzce population tended to show negative values along the CA1 and CA2 axes. While the Bolu population indicated positive and negative values on the CA2 axes.

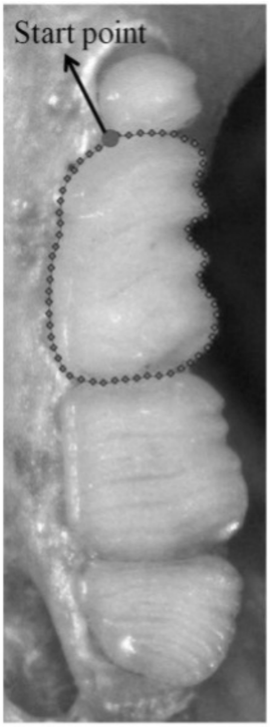

Figure 2. Occlusal surface of the left first upper molar and start position of digitisations.

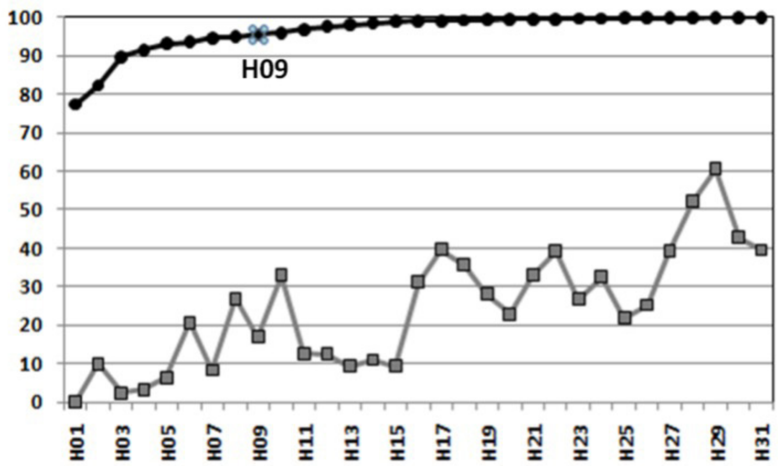

Figure 3. Harmonic order for the left first upper molar of *M. avellanarius*.

4. Discussion

The hazel dormouse, *M. avellanarius* is distributed across Northwest Anatolia and Northeast Black Sea regions. These regions have some formations, which can affect population structure, such as different vegetation, climate, glacial refugia, topography, and some physical barriers; the Kızılırmak River and the Melet River. Kıvanç (1983) analysed a wide range of samples based on morphological characteristics and described new subspecies, *M. avellanarius abanticus* from Abant (Soğuksu) and *M. avellanarius trapezius* based on traditional morphometrics analysis. Kıvanç (1989), Kıvanç and Yardımcı (2000), and Kankılıç et al. (2021) testified the validity of two subspecies based on tooth variations and karyological aspects, respectively.

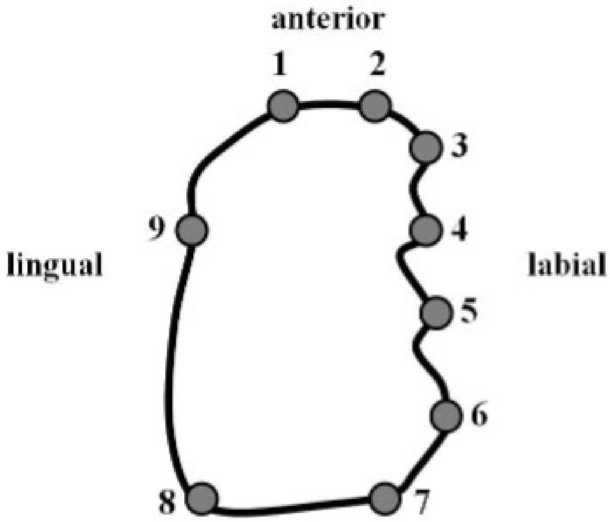

Figure 4. Positions of nine landmarks for the left first upper molar (Definitions are in the text).

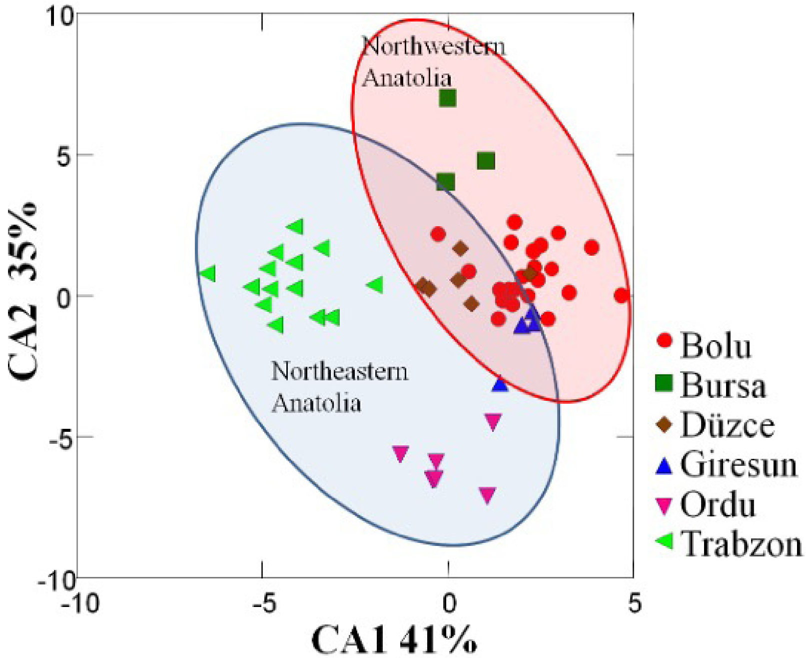

Figure 5. Canonical variate analysis of *M. avellanarius* on the M1 for outline analysis.

M. avellanarius is a hibernator species and needs complex habitat requirements (Foppen et al., 2002; Vilhelmsen, 2003; Bright et al., 2006). Changes in geographical climate and vegetation may allow *M. avellanarius* to have different morphological aspects of its molars by its main range in Turkey as in another glirid, *Glis glis* (Helvacı et al., 2012). Helvacı et al. (2012) indicated that *G. glis* has diversity based on this eco-region pattern, inferred from the first upper molar shape analysis. We analysed specimens from both the west and the east of the Melet River; however, our findings did not reveal an isolated effect of the Melet River on populations of *M.*

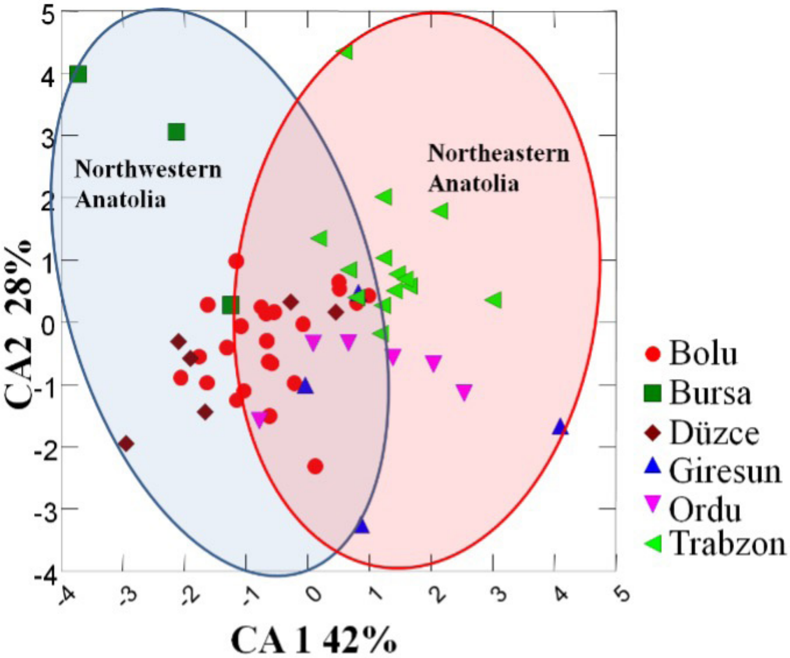

Figure 6. Canonical variate analysis of *M. avellanarius* on the M1 for landmark analysis.

avellanarius in the region. The Northern Black Sea shores of Anatolia are covered with humid deciduous forests and the forest ecosystem has plant communities rich in species. Specimens from Ordu, Giresun, and Trabzon overlapped on the range of *M. a. trapezius*. This might have resulted from ecological differentiation. Atalay and Efe (2010) and Atalay et al. (2014) indicated that forests in Giresun, Ordu, and Trabzon (Northeastern Anatolia) are richer in species and understorey than the forest ecosystems in the west. Interestingly, Bursa and Trabzon populations showed positive values on CA2 axes (Figure 6). Bursa has the weakest understorey vegetation among these localities (Ordu, Giresun, and Trabzon) (Atalay and Efe, 2010; Atalay et al., 2014).

In this study, we determined the separation of *M. avellanarius* into a Northwest group corresponding to *M. a. abanticus* and a Northeast Anatolia group corresponding to *M. a. trapezius* based on an outline analysis (Figure 5) and landmark analysis on the first upper molar (Figure 6). These findings supported the possible effect of the Kızılırmak River on the divergence of *M. avellanarius* to two different subspecies, *M. a. trapezius* and *M. a. abanticus*. However, to justify this case, further research is necessary on specimens from the near west and east banks of the Kızılırmak River.

Feeding biology is an important factor to understand an animal's ecology (Kaya and Kaymakçı, 2013). Glirid tooth morphology has taken shape throughout the Cenozoic period (Daams and De Bruijn, 1995) and tooth diversification arose because of hard food consumption (Daams and Van der Meulen, 1984) across phylogeny (Caumul and Polly, 2005). According to microwear analysis, Kaya and Kaymakçı (2013) noted that dormice had complex diets (e.g., grass, insect, seeds, and fruit) in the Sivas Basin, in eastern Central Anatolia. Similarly, Oliver (2014) indicated that the molar tooth morphology of *Armantomys* (an extinct genus of Gliridae in Spain) depends on its varied diet. Also, teeth characteristics of dormice are often used for their classification (García - Alix et al., 2008). Shape analysis is related to feeding biology and it describes geographic variation in teeth characteristics (Renaud, 2005). According to fossil records, the molar teeth of rodents evolved from brachydont to hypselodont based on vegetation change (Tapaltsyan et al., 2015). It is thought that teeth evolution was related to feeding biology and their abrasive characteristics allowed a wide range of food (Tapaltsyan et al., 2015).

M. avellanarius generally prefers hazel and bramble (Bright et al., 2006) but feeds miscellaneously according to season (Bright and Morris, 1993), also preferring seeds, flowers, and berries (Juškaitis, 2007). The hazelnut is a major source of nutrition for the hazel dormouse in Turkey. On the other hand, Northern Anatolia has many rivers. The division of the distribution area with rivers and the local vegetation difference may have caused this species to be biogeographically different, as seen in our results. Also, because this species lives in short-range habitats (Mortelliti et al., 2010) and accordingly adapt to these different habitats, populations may cluster discretely like in this study (Figures 5 and 6). However, the addition of hard food, such as oak seeds, to the feeding habits may have caused a differentiation in tooth morphology in Northwest Anatolia.

It is considered low dispersal of this species (Bright and Morris, 1992; Mortelliti et al., 2010), habitat loss, habitat fragmentation, and destroyed forest composition becomes more important.

In this study, both outline analysis (Figure 5) and landmark analysis (Figure 6) results showed significant differences in the first upper molar shape for the hazel dormouse, *M. avellanarius*. Our results showed that populations were grouped as Northwest and Northeast Anatolia. Consequently, although there appears to be a clear difference between populations, to say that these groups are subspecies for this distinction between the Northwest Anatolia and Northeast Anatolia populations would be an overstatement based on the current study. Perhaps these populations are on their way toward being an ecological race or subspecies, but there is a need for further studies supported by larger and molecular data.

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References

Amori G (1993). Italian insectivores and rodents: extinctions and current status. Supplemento alle Ricerche di Biologia della Sevaggina 21: 115-134.

Atalay İ, Efe R (2010). Structural and distributional evaluation of forest ecosystems in Turkey. Journal of Environmental 31: 61-70.

Atalay İ, Efe R, Öztürk M (2014). Ecology and classification of forests in Turkey. Procedia-Social and Behavioral Sciences 120: 788-805. https://doi.org/10.1016/j.sbspro.2014.02.163

Auffray JC, Renaud S, Claude J (2009). Rodent biodiversity in changing environments. Kasetsart Journal, Natural Sciences 43: 83-93.

Bright PW, Morris PA (1991). Ranging and nesting behaviour of the dormouse, *Muscardinus avellanarius*, in diverse low-growing woodland. Journal of Zoology 224: 177-190.

Bright PW, Morris PA (1992). Ranging and nesting behaviour of the dormouse *Muscardinus avellanarius*, in coppice-with-standards woodland. Journal of Zoology 226: 589-600. https://doi.org/10.1111/j.1469-7998.1992.tb07502.x

Bright PW, Morris PA (1993). Foraging behaviour of dormice *Muscardinus avellanarius* in two contrasting habitats. Journal of Zoology 230: 69-85. https://doi.org/10.1111/j.1469-7998.1993.tb02673.x

Bright PW, Morris PA, Mitchell - Jones T (2006). The Dormouse Conservation Handbook. 2nd ed. Peterborough: English Nature.

Capizzi D, Battistini M, Amori G (2002). Analysis of the hazel dormouse, *Muscardinus avellanarius*, distribution in a Mediterranean fragmented woodland. Italian Journal of Zoology 69: 25-31. https://doi.org/10.1080/11250000209356434

Cardini A (2003). The geometry of the marmot (Rodentia: Sciuridae) mandible: phylogeny and patterns of morphological evolution. Systematic Biology 52: 186-205. https://doi.org/10.1080/10635150390192807

Caumul R, Polly PD (2005). Phylogenetic and environmental components of morphological variation: Skull, mandible, and molar shape in marmots (Marmota, Rodentia). Evolution 59 (11): 2460-2472. https://doi.org/10.1111/j.0014-3820.2005.tb00955.x

Cerling TE, Harris JM, MacFadden BJ, Leakey MG, Quade J et al. (1997). Global vegetation change through the Miocene/Pliocene boundary. Nature 389: 153-158.

Daams R, De Bruijn H (1995). A classification of the Gliridae (Rodentia) on the basis of dental morphology. Hystrix - the Italian Journal of Mammalogy 6: 1-2. https://doi.org/10.4404/hystrix -6.1 - 2 - 4015

Daams R, Van der Meulen A (1984). Paleoenvironmental and paleoclimatic interpretation of micromammal faunal successions in the upper Oligocene and Miocene of north-central Spain. Paleobiologie Continentale 14: 241 - 257.

Dayan T, Wool D, Simberloff D (2002). Variation and covariation of skulls and teeth: modern carnivores and the interpretation of fossil mammals. Paleobiology 28 (4): 508-526. https://doi.org/10.1666/0094-8373(2002)028%3C0508:VACOSA%3E2.0.CO;2

Doğramacı S and Kefelioğlu H (1992). Türkiye *Muscardinus avellanarius* (Mammalia: Rodentia) türünün karyotipi. Doğa Turkish Journal of Zoology 16: 43-49.

Dubey S, Zaitsev M, Cosson JF, Abdukadier A, Vogel P. (2006). Pliocene and Pleistocene diversification and multiple refugia in a Eurasian shrew (*Crocidura suaveolens* group). Molecular Phylogenetics and Evolution 38: 635-647. https://doi.org/10.1016/j.ympev.2005.11.005

Echeverry AM, Londoño-Cruz E, Benítez HA (2020). Quantifying the geometric shell shape between populations of true limpets lotta mesoleuca (Mollusca: Lottidae) in Colombia. Animals 10 (4): 675. https://doi.org/10.3390/ani10040675

Ellerman JR (1948). Key to the rodents of southwest Asia in the British Museum collection. Proceedings of the Zoological Society of London 118: 765-816.

Foppen R, Verheggen L, Boonman M (2002). Biology, status and conservation of the hazel dormouse (*Muscardinus avellanarius*) in the Netherlands. Lutra 45: 147-154.

Fortelius M, Eronen J, Jernvall J, Liu L, Pushkina D et al. (2002). Fossil mammals resolve regional patterns of Eurasian climate change over 20 million years. Evolutionary Ecology Research. 4: 1005-1016.

Freudenthal M, García - Alix A, Rios M, Ruiz - Sánchez F, Martín - Suárez E et al. (2014). Review of paleo - humidity parameters in fossil rodents (Mammalia): Isotopic vs. tooth morphology approach. Palaeogeography, Palaeoclimatology, Palaeoecology 395: 122-130. https://doi.org/10.1016/j.palaeo.2013.12.023

García - Alix A, Minwer - Barakat R, Martín - Suárez E, Freudenthal M (2008). *Muscardinus meridionalis* sp. nov., a new species of Gliridae (Rodentia, Mammalia) and its implications for the phylogeny of *Muscardinus*. Journal of Vertebrate Paleontology 28: 568-573. https://doi.org/10.1671/0272-4634(2008)28[568:MMSNAN]2.0.CO;2

Gomez Cano AR, Hernandez Fernandez M, Alvarez - Sierra MA (2013). Dietary ecology of Murinae (Muridae, Rodentia): a geometric morphometric approach. PLoS One 8: e79080. https://doi.org/10.1371/journal.pone.0079080

Goodwin CED, Suggitt AJ, Bennie J, Silk MJ, Duffy JP et al. (2018) Effects of climate, landscape, habitat, and woodland management associations with hazel dormouse *Muscardinus avellanarius* population status. Mammal Review 48: 209-223. https://doi.org/10.1111/mam.12125

Heard SB, Hauser DL (1995). Key evolutionary innovations and their ecological mechanisms. Historical Biology 10: 151-173. https://doi.org/10.1080/10292389509380518

Helvacı Z, Çolak E. (2021). New data on the taxonomy of the Genus *Apodemus* Kaup, 1829 (Mammalia: Rodentia) in Turkey: A geometric morphometric approach. Acta Zoologica Bulgarica 73 (4): 503-509. https://hdl.handle.net/20.500.12451/9145

Helvacı Z, Renaud S, Ledevin R, Adriaens D, Michaux J et al. (2012). Morphometric and genetic structure of the edible dormouse (*Glis glis*): a consequence of forest fragmentation in Turkey. Biological Journal of the Linnean Society 107: 611-623. https://doi.org/10.1111/j.1095 - 8312.2012.01952.x

Hutterer R, Kryštufek B, Yiğit N, Mitsain G, Meinig H et al. (2016). *Muscardinus avellanarius.* The IUCN Red List of Threatened Species.

Juškaitis R (2007). Feeding by the common dormouse (*Muscardinus avellanarius*): a review. Acta Zoologica Lituanica 17: 151-159. https://doi.org/10.1080/13921657.2007.10512827

Juškaitis R (2008). The Common Dormouse *"Muscardinus Avellanarius"*: Ecology, Population Structure and Dynamics, Institute of Ecology of Vilnius University Publishers.

Kankılıç T, Şeker PS, Selvi E, Özkan B, Yiğit N et al. (2021). G-banded karyotypes of some species in Gliridae (Mammalia: Rodentia) from Turkey. Adıyaman University Journal of Science 11 (1): 59-72. https://doi.org/10.37094/adyujsci.830056

Kaya F, Kaymakçı N (2013). Systematics and dental microwear of the late Miocene Gliridae (Rodentia, Mammalia) from Hayranlı, Anatolia: implications for paleoecology and paleobiodiversity. Palaeontologia Electronica 16: 1-22. https://doi.org/10.26879/385

Kıvanç E (1983). Die Haselmaus, *Muscardinus avellanarius* L.,in der Türkei. Bonner zoologische Beiträge 34: 419 - 428.

Kıvanç, E (1989). Türkiye Fındık Faresinde, *Muscardinus avellanarius* (Linnaeus, 1758) Diş Köklerinin Varyasyonu. Doğa. Turkish Journal Biology 13 (1): 29-34 (in Turkish).

Kıvanç E, Yardımcı M (2000). Türkiye fındık faresinde (*Muscardinus avellanarius* L.,1758) molarların çiğneme yüzeylerinin yapısı. Gazi Üniversitesi Fen Bilimleri Enstitüsü Dergisi 13 (4):1047-1057 (in Turkish).

Ledevin R, Michaux JR, Deffontaine V, Henttonen H, Renaud S (2010). Evolutionary history of the bank vole *Myodes glareolus*: a morphometric perspective. Biological Journal of the Linnean Society 100: 681-694. https://doi.org/10.1111/j.1095-8312.2010.01445.x

Michaux J, Chevret P, Renaud S, Research E (2007). Morphological diversity of old-world rats and mice (Rodentia, Muridae) mandible in relation to phylogeny and adaptation. Journal of Zoological Systematics and Evolutionary Research 45: 263-279. https://doi.org/10.1111/j.1439 - 0469.2006.00390.x

Miller GS (1908). New mammals from Asia Minor. Annals And Magazine of Natural History 8 (1): 69-70. https://doi.org/10.1080/00222930808692358

Morris P (2003). A review of research on British dormice (Gliridae) and the effect of increasing public and scientific awareness of these animals. Acta Zoologica Academiae Scientiarum Hungaricae 49: 125-130.

Mortelliti A, Amori G, Capizzi D, Rondinini C, Boitani L (2010). Experimental design and taxonomic scope of fragmentation studies on European mammals: current status and future priorities. Mammal Review 40: 125-154. https://doi.org/10.1111/j.1365 - 2907.2009.00157.x

Mortelliti A, Sozio G, Driscoll DA, Bani L, Boitani L, Lindenmayer DB. (2014). Population and individual-scale responses to patch size, isolation and quality in the hazel dormouse. Ecosphere 5 (9): 1-21. https://doi.org/10.1890/ES14 - 00115.1

Nehring A. (1903). *Muscardinus avellanarius* und *Myoxus glis orientalis*, nov. Subsp., aus Kleinasien. Sitzungsberichte der Gesellschaft Naturforschender Freunde 4: 187-188.

Okay AI, Topuz G. (2017). Variscan orogeny in the Black Sea region. International Journal of Earth Sciences 106: 569-592. https://doi.org/106:569-592.10.1007/s00531-016–1395-z

Oliver A (2014). Dental microwear analysis in Gliridae (Rodentia): methodological issues and paleodiet inferences based on *Armantomys* from the Madrid Basin (Spain). Journal of Iberian Geology 40: 157-166. https://doi.org/10.5209%2Frev_JIGE.2014.v40.n1.44096

Parés - Casanova PM, Salamanca - Carreño A, Crosby-Granados RA, Bentez - Molano J (2020). A comparison of traditional and geometric morphometric techniques for the study of basicranial morphology in horses: a case study of the Araucanian horse from Colombia. Animals 10 (1): 118. https://doi.org/10.3390/ani10010118

Popov SV, Rögl F, Rozanov AY, Steiniger FF, Shcherba IG, et al (2004). Lithological-paleogeographic maps of Paratethys: 10 maps Late Eocene to Pliocene. Courier Forschunginstitut Senckenberg 250: 1 - 46.

Popov SV, Shcherba IG, Ilyina LB, Nevesskaya LA, Paramonova NP et al (2006). Late Miocene to Pliocene palaeogeography of the Paratethys and its relation to the Mediterranean. Palaeogeography, Palaeoclimatology, Palaeoecology, 238: 91-106. https://doi.org/10.1016/j.palaeo.2006.03.020

Renaud S (2005). First upper molar and mandible shape of wood mice (*Apodemus sylvaticus*) from northern Germany: ageing, habitat and insularity. Mammalian Biology 70: 157 - 170. https://doi.org/10.1016/j.mambio.2004.10.004

Renaud S, Michaux JR (2007). Mandibles and molars of the wood mouse, *Apodemus sylvaticus* (L.): integrated latitudinal pattern and mosaic insular evolution. Journal of Biogeography 34: 339-355. https://doi.org/10.1111/j.1365 - 2699.2006.01597.x

Renaud S, Michaux J, Jaeger J.J, Auffray, JC (1996). Fourier analysis applied to *Stephanomys* (Rodentia, Muridae) molars: nonprogressive evolutionary pattern in a gradual lineage. Paleobiology 22: 255-265.

Samuels JX (2009). Cranial morphology and dietary habits of rodents. Zoological Journal of the Linnean Society 156: 864-888. https://doi.org/10.1111/j.1096 - 3642.2009.00502.x

Şekeroğlu V, Kefelioğlu H, Şekeroğlu ZA. (2011). G - and C - banded karyotypes of hazel dormouse, *Muscardinus avellanarius trapezius* (Mammalia: Rodentia) in Turkey. Turkish Journal of Zoology 35 (3): 375-379. https://doi.org/10.3906/zoo-0907-95

Tapaltsyan V, Eronen JT, Lawing AM, Sharir A, Janis C et al. (2015). Continuously growing rodent molars result from a predictable quantitative evolutionary change over 50 million years. Cell reports 11: 673-80. https://doi.org/10.1016/j.celrep.2015.03.064

Vilhelmsen H (2003). Status of dormice (*Muscardinus avellanarius*) in Denmark. Acta Zoologica Academiae Scientiarum Hungaricae 49: 139-146.

Williams SH, Kay RF (2001). A comparative test of adaptive explanations for hypsodonty in ungulates and rodents. Journal of Mammalian Evolution 8: 207-229. https://doi.org/10.1023/A:1012231829141

Wilson DE, Reeder DM (2005). Mammal species of the world: a taxonomic and geographic reference. JHU Press

Yamada E, Anezaki T, Hong H (2018). Tooth outline shape analysis of the Ryukyu Wild Boar (*Sus scrofa riukiuanus*) and the Japanese Wild Boar (*S. s. leucomystax*) by geometric morphometrics. Mammal Study 43 (2): 99-107. https://doi.org/10.3106/ms2017 - 0080

Yiğit N, Çolak E, Sözen M, Karataş A (2006). Rodents of Türkiye. Meteksan Company, Ankara, 154p.