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STUDIES OF ECOMORPHOLOGICAL VARIATIONS OF THE EUROPEAN HARE (*LEPUS EUROPAEUS*) IN TURKEY

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Abstract - Hares (*Lepus* spp.) are widely distributed across the globe and are adapted to diverse climatic conditions. In order to study the ecomorphological variations of hares from Turkey, the body and cranial measurements and body weight, as well as coat color types, of 138 hares collected from all over Turkey between 2006 and 2012, were examined. Statistically significant differences between regional samples ($p < 0.05$, ANOVA) only in terms of body weight and hindfoot length were found; however, there were a good number of external phenotypes, particularly in terms of coat color variants of the hare specimens. Furthermore, populations had similar variations in terms of morphometric measurement, body weight and coat coloration between different geographical regions. Turkish hares did not exhibit clinal variations from south to north in body and cranial measurements depending on the mean annual temperatures and precipitation. Therefore, it was assumed that all of these variations might be a polymorphism related to the local adaptations and high level of admixture of gene pools in Anatolia.

Key words: European hare, *Lepus europaeus*, ecomorphological variation, polymorphism, Turkey

INTRODUCTION

Turkey possesses different geological, climatological, phytogeographical and zoogeographical characteristics due to the fact that it is located between Europe and Asia. Orogenic events, migrations and anthropological influences together with glacial and interglacial periods have changed the genetic structure of mammals in Anatolia. After Anatolia had completed its geological formation, many species of Palearctic, Ethiopian and Oriental origin entered into the area (i.e., ancient boreal elements gene flow from Europe via the early Holocene land bridge, boreal and Siberian gene flow from Caucasia, gene flow from eastern and southeastern steppes and deserts, from central Mesopotamia, and the Arabian Peninsula, and via the latter route African elements reached Anatolia), and in the process of evolutionary change, some endemic species have also appeared in Anatolia (Demirsoy, 2008). In this respect, it is considered that Turkey has a high rate of endemism and an important position in biological richness.

Hares and jackrabbits (genus *Lepus*) are a taxonomically notoriously difficult group, mainly due to high degree of morphological variations and the potential of rapid adaptation to the environmental factors. They can live in a variety of terrestrial ecosystems due to their high adaptability (Flux and Angermann, 1990). Hares from Turkey are considered as European hares (*Lepus europaeus*) and initial molecular and morphometric analyses seem to confirm that fact (Sert et al., 2005, 2009; Demirbaş et al., 2010; Demirbaş, 2010a). More details of taxonomic status, population genetics and the phylogeny of the hares of Turkey will be published elsewhere.

Lepus europaeus, spreading all over Turkey, can be found in various ecosystems such as steppes, forests, bushes, plateaus, woodlands and agricultural areas (Demirbaş, 2010).

Misonne (1957) recorded the *Lepus europaeus* from Birecik, Ceylanpınar and Viranşehir near Şanlıurfa in Anatolia. Osborn (1964) stated that the European hare existed in Turkey. Huş (1967) reported the existence of *Lepus europaeus syriacus* in Trabzon, Turkey. Turan (1984) stated that European hare spread around the whole Turkey. Additionally, there is a limited amount of studies about hare in Turkey (Doğramacı, 1989; Oğurlu, 1997; Yiğit et al., 2006). Sert (2006) has examined the effects of temperature and precipitation on the morphology of hare in Anatolia. Temizer and Önel (2011) investigated the hares of Elazığ and Malatya in terms of morphometrical measurements. Tez et al. (2012) reported on some of the morphological characteristics of the hares from the Asian part of Turkey. However, all these studies were restricted in terms of sample size and geographical area. That is to say, the ecomorphological variations of Turkish hares have not been fully examined. This study aims to find out the variations of European hare (*Lepus europaeus*) in different geographic regions from all over Turkey and to evaluate them ecomorphologically.

MATERIALS AND METHODS

This study is based on 138 hare specimens obtained from 55 different localities up to an altitude of 2200 m from across Turkey between 2006 and 2012. In addition to this, the coat colors of two specimens in the Museum of Archaeology and Ethnography in Kırklareli (Turkey) have also been recorded. The environmental conditions in Turkey are characterized by a rainy, humid and temperate boreal climate in northern Turkey, especially in the northern part of the North Anatolian Mountains (mean annual precipitation from 60-220 cm locally; mean temperature in July between 15-26°C locally; mean temperature in January between 4-10°C locally); hot and dry eremial climate in the southeastern parts (mean annual precipitation from 30-60 cm locally; mean temperature in July is above 32°C; mean temperature in January changes between 5-12°C locally); a Siberian-type climate in the east which is especially cold and dry in winters (mean annual precipitation from 30-300 cm locally; mean temperature in July between 20-30 °C locally; mean temperature in January is below -4°C or between -2 to 0°C locally); Mediterranean climate which is hot and dry in the summer and wet and warm in winter in the west and southwest (mean annual precipitation from 40-200 cm locally; mean temperature in July between 20-32°C locally; mean temperature in January changes between 6-12°C locally) and a terrestrial climate which lacks rain and is arid and hot in summers, and cold and snowy in winters in the central parts of Turkey (mean annual precipitation from 20-50 cm locally; mean temperature in July between 20-30°C locally; mean temperature in January between 0-10°C locally), respectively. Moreover, the Marmara region (the northwestern part of Turkey) has the characteristics of a transition climate between terrestrial, boreal and Mediterranean climates (mean annual precipitation from 40-150 cm locally; mean temperature in July between 15-26°C locally; mean temperature in January between 0-8°C locally). In these different regions, many microclimates can be observed depending on the altitude. Even within very close distances there may be very different climates; for instance, the Iğdır Plain (in the eastern Turkey, close to the borders of Armenia and Iran) has a Mediterranean semi-tropical climate, while Mount Ararat (40 kilometers to Iğdır) and its plateau have a type of Siberian climate. These differences in climate have allowed a high biodiversity in Turkey (Fig 1).

Field work was performed under the surveillance of the General Directorate of Nature Protection and National Parks and with the permission of Ministry of Forestry and Waterworks. Specimens were prepared as museum type according to Mursaloğlu (1965) and are deposited at the Biology Department, Science and Arts Faculty of Kırıkkale University.

Specimens were divided into three age groups: infant, juvenile and adult, according to the "Stroh sign" which is located at the tip of the ulna bone (Stroh,

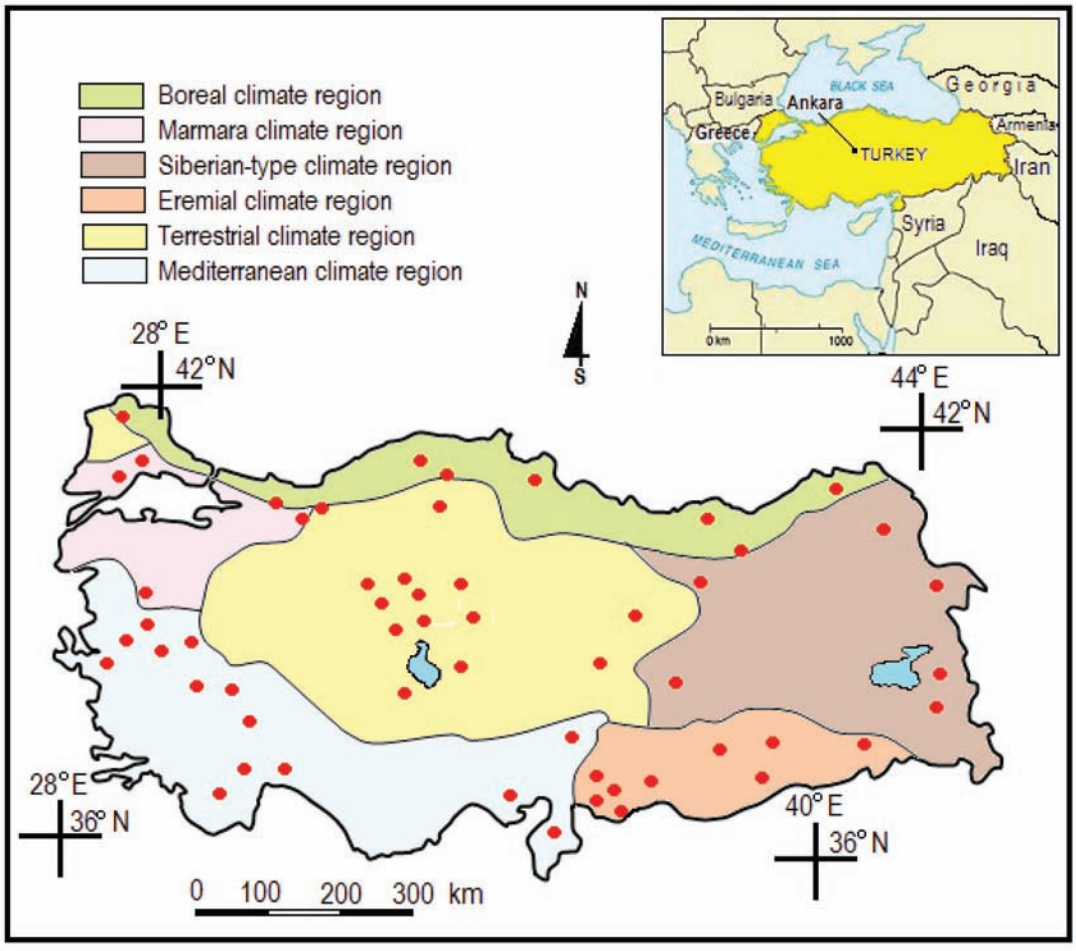

Fig 1. Red dots indicate local samples of one or more individuals and colored areas indicate diverse climate regions across Turkey.

1931), the pronouncedness of sutures in the cranial bones (between the frontal and sagittal bones) and the morphological structure of processus supraorbitalis (Suchentrunk et al., 2000), external measurements and weight in infant animals (Bray et al., 2002) and field notes concerning the size of testis and status of lactation. Only the adult group (n=97) was used for comparisons and evaluations. External and cranial measurements of the specimens were taken using a tape measure and a dial caliper with an accuracy of 0.05 mm according to Angermann (1968), Nagorsen (1985) and Harrison and Bates (1991). Sexual differences within the adult group were investigated using specimens of known sex by the t test. Measures of both sexes were evaluated together because no statistically significant difference was found. For the statistical analysis and graphs, the Statistical Package for the Social Sciences (SPSS 18 (PASW)) was used. Whether group averages were equal or not was tested by Analysis Of Variance (ANOVA). As a *post hoc* test, the Tukey's Test was used. For morphometrical comparisons of specimens of European hare in Turkey, the box plots were given.

RESULTS

The body weights, body measurements (total length, tail length, hind length, ear length) and some distinctive cranial measurements (condylobasal length, nasal length, upper molar length, zygomatic breadth,

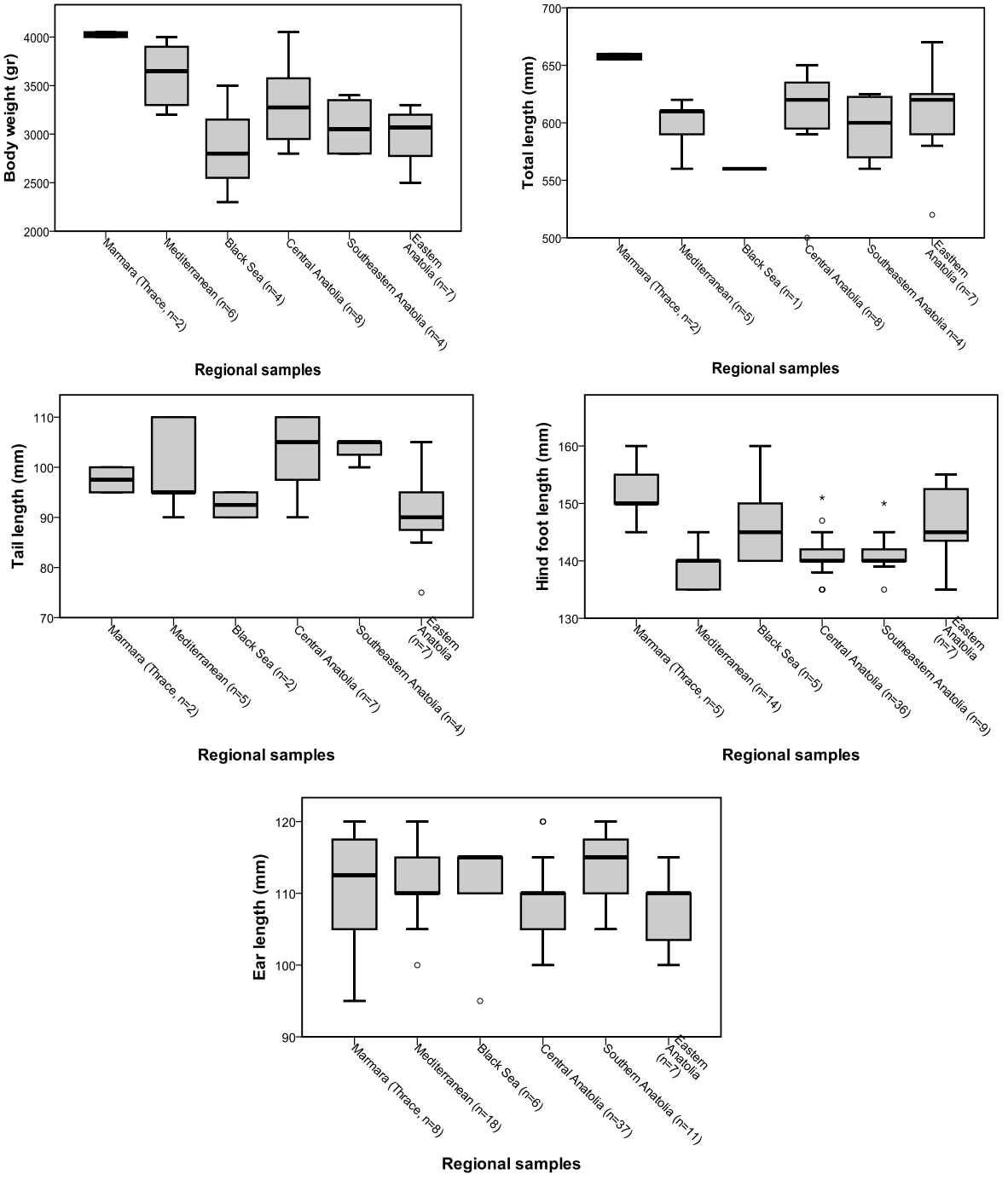

Fig. 2. Comparison of Turkish hares in terms of external measurements and weight via box plots

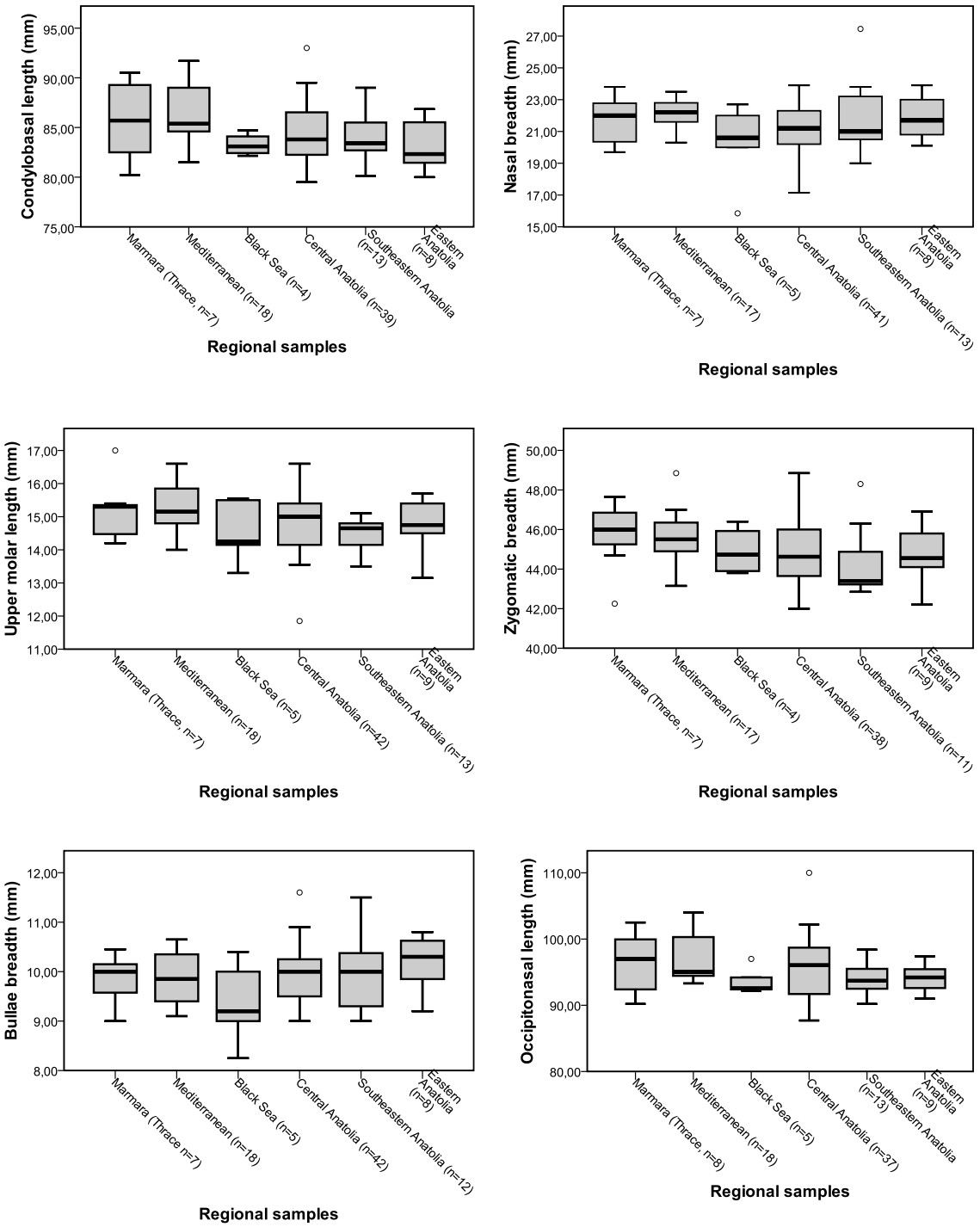

Fig. 3. Comparison of Turkish hares in terms of cranial measurements via box plots

bulle breadth, occipitonasal length) were compared between the given groups in terms of environmental factors. The analyses performed showed that there was no statistically important difference between the groups in terms of total length, tail length, ear length, condylobasal length, occipitonasal length, nasal length, upper molar length, zygomatic breadth and bulle breadth. ($P < 0.05$). However, there were statistically important differences between the groups in terms of body weight and hind lengths ($P < 0.05$).

As regards body weight, the Marmara samples were on average 1158 grams heavier than the Black Sea samples and 1050 grams heavier than the eastern Anatolia samples ($P < 0.05$). The hind lengths of the Marmara samples were 13 mm longer than the Mediterranean, 11.4 mm longer than the central Anatolian and 10.9 mm longer than the southeastern Anatolian samples, respectively. Moreover, the Mediterranean samples were on average 8 mm shorter than the Black Sea and 7.7 mm shorter than the eastern Anatolian samples, respectively ($P < 0.05$). (Figs. 2 and 3).

Furthermore, a good number of external phenotypes (i.e., the types of coat color) were recorded from different regions of Turkey. The dominant coat colorations in the different regions were as follows: in western Turkey, grayish light brown-pale yellow coat; in central and eastern Anatolia, slightly grayish/blackish and yellowish light brown coat; in the Black Sea region, slightly blackish light brown coat; in the central parts of southeastern Anatolia, slightly yellowish pale light brown coat; in Artvin (northeastern Black Sea), slightly yellowish pale black coat; in Kahramanmaraş (with a special microclimate between the central and southeastern Anatolia), pale wheat colored coat; and in the provinces of Hatay, Kilis and Şanlıurfa in the southeastern Anatolia, pale light yellowish brown (yellowish type in general)

DISCUSSION

Environmental factors are one of the important determinants of postnatal skull ontogeny (Hall, 1990) and final size (Burnett, 1983; Calder, 1984; Schmidt-Nielsen, 1984; Yom-Tov and Nix, 1986; Wigginton and Dobson, 1999; Yom-Tov and Geffen, 2006). The body and skull sizes of animals are usually considered positively correlated with a decrease in temperature. This is known as Bergmann's rule. Although body mass is the most common reference point for size (Meiri et al., 2004), food availability and fasting endurance are the main determinants of body size (Millar and Hickling, 1990), and seasonal changes in body mass have been observed in many mammals species. Thus, unlike body mass, the skeleton of mammals is a comparatively stable feature. Liao et al. (2006) revealed that Bergmann's rule is not universally valid for interpreting animal body size clines, particularly in large mammalian species. Lu (2003) also stated that since infant hares are born in different seasons, they do not conform to it. On the contrary, Yom-Tov (1967) stated that Israeli hares showed direct clinal variation from south to north in body and cranial measurements depending on the mean annual temperature and precipitation. Our study suggested that environmental conditions and nutrients do not have much effect on the body and cranial measurements of hares from Turkey, because there were significant differences only in body weight and hindfoot length. However, it should be kept in mind that one of the different findings of ours was body weight. In addition, our results revealed that Turkish hares did not show a direct clinal variation from south to north in body and cranial measurements depending on the mean annual temperature and precipitation. Sert (2006) recorded that condylobasal length shows a significant variation in specimens separated by distance (i.e., between Europe, Anatolia and South African populations), and it reaches the highest value in the Europe, which has the lowest mean temperature. Temizer and Önel (2011) determined that there was no difference in terms of cranial measurements between Malatya and Elazığ specimens in Anatolia, where the populations are close to each other.

Mitchell-Jones et al. (1999) reported that *Lepus europaeus* subspecies in Europe have different coat color types. Suchentrunk et al. (2000) discussed the effects of ecogenetic factors on coat color and body size in Israeli hares. The authors stated that regional

variations in their external appearances, such as coat coloration, fur texture, body size and ear length, are governed mainly by ecogenetic factors, and Israeli hares have retained a broad phenotypic plasticity in external appearance. Sert (2006) recorded that the variations in coat color occurred by means of the narrowing and expansion of light and dark bands on the hair or the disappearance of some bands. He also stated that cranial measurements, coloration and thickness of hair depended on temperature and precipitation. Our study revealed that the hares of Turkey have comparatively diverse seasonal and regional coat color types; however, winter coat colors differ slightly from summer coat color. We presumed that the diversity and admixture observed in the same region and between geographic regions in terms of coat color types in Turkish hares might be a clear signal of different gene flows into Anatolia from neighboring regions. Sert et al. (2005) suggested that there was little genetic differentiation between the two forms with different coat color (brownish and yellowish ones) in Anatolian hares. On the other hand, Demirbaş et al. (2010) recorded that the yellowish samples in southeastern Anatolia have a low-level chromosomal difference from the brownish ones.

Sert et al. (2005) pointed out that Anatolian hares have a high genetic diversity. This information may be also confirmed through differences in coat color. Namely, these differences in coat color may reflect different gene pools in Anatolia. The genetic structures of Turkey hares will be published in another journal. Yom-Tov (1967) noted that the coat colors of Israeli hares closely follow the color of the soil. Although our findings were generally similar with his, the findings of our specimens in some regions, particularly in southeastern Anatolia, did not have this kind of similarity.

In this study, it was determined that specimens of Turkish hare varied in types of coat color, body weight and hindfoot length depending on geography, and similar variations in coat coloration, body weight and measurements were even observed in different geographical regions. We assumed that all these differences might be based on polymorphism. Moreover, the morphometric analysis confirmed that they were all *Lepus europaeus*, despite any variations in pelage coloration reflecting local adaptation.

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