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Abundance of *Apodemus* spp. varies by stand age in coppice-originated oak forest, Thrace, Turkey

La abundancia de *Apodemus* spp. varía con la edad del rodal de encina originado de monte bajo, Tracia, Turquía

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SUMMARY

Recently, oak (*Quercus* spp.) management strategies in Turkey have transitioned from predominantly coppice-regeneration to seed regeneration. However, impacts of this change on the small mammal community is unknown. To address this issue we evaluated abundance of *Apodemus* spp. (Rodentia, Muridae) in relation to stand age and forest characteristics in the northern Thrace, Turkey. We sampled 43 plots using box-style live traps. A total of 75 individuals (0.125 ± 0.013 mice/trap nights) was captured. *Apodemus flavicollis* (n = 69) was the most abundant, although *A. agrarius* (1) and *A. sylvaticus* (4) also occurred. *Apodemus* spp. abundance was superior in older than in younger stands ($P = 0.038$). The number of specimens was positively related to diameter at breast height (DBH) ($y = 0.18 + 0.015x$, $R^2 = 0.21$) and forest floor mass ($y = 0.005 + 0.00005x$, $R^2 = 0.22$). Increasing the amount of forest floor mass and mast production will benefit the population of *Apodemus* spp. Abandonment of the coppice management on oak forests in Thrace may positively affect the local abundance of *Apodemus* spp., particularly *A. flavicollis*.

Key words: *Apodemus flavicollis*, diameter at breast height (DBH), forest floor.

RESUMEN

Recientemente, las estrategias de manejo de encina (*Quercus* spp.) en Turquía han pasado de ser predominantemente de regeneración por monte bajo a regeneración por semillas. Sin embargo, los efectos de este cambio en la comunidad de mamíferos pequeños son desconocidos. Para hacer frente a estos problemas se evaluó la abundancia de *Apodemus* spp. (Rodentia, Muridae) en relación con la edad del rodal y las características de los bosques en el norte de Tracia, Turquía. Fueron muestreadas 43 parcelas utilizando trampas vivas de estilo caja. Se capturaron 75 individuos (0,125 ± 0,013 ratones por trampa y noche). *Apodemus flavicollis* (n = 69) fue más abundante, pero *A. agrarius* (1) y *A. sylvaticus* (4) también se presentaron. La abundancia de *Apodemus* spp. fue mayor en los rodales más viejos que en los más jóvenes ($P = 0{,}038$). El número de individuos se relacionó positivamente con el diámetro a la altura del pecho (DAP) ($y = 0{,}18 + 0.015x$, $R^2 = 0{,}21$) y con la masa de mantillo ($y = 0{,}005 + 0.00005x$, $R^2 = 0{,}22$). El aumento de la cantidad de mantillo y de los fustes beneficiará a la población de *Apodemus* spp. El abandono del manejo de monte bajo en bosques de encina en Tracia puede afectar positivamente la abundancia local de *Apodemus* spp., en particular *A. flavicollis*.

Palabras clave: *Apodemus flavicollis*, diámetro a la altura del pecho (DAP), piso del bosque.

INTRODUCTION

Small mammals are generally viewed as pests in agricultural areas around the world (Quin *et al.* 2000). Nonetheless, in forested areas, small mammals are important as dispersers of mycorrhizal fungi (Terwilliger and Pastor 1999), as prey items for predators (Jędrzejewski and Jędrzejewska 1992), as influential biotic agents on physical and chemical properties of soil and as predators of insects and other small animals (Sieg 1987). The genus *Apodemus* (Rodentia, Muridae), which is comprised by true mice and rats, is distributed in the Palearctic Region (Krystufek and Vohralik 2007). *Apodemus* spp. predominates in forested areas. Although a number of studies have occurred on mice in Europe, the relation between habitat characteristics and rodent abundance is still equivocal (Khidas *et al.* 2002). Information on the *Apodemus* genus was limited, during the conversion of coppice to high oak forest and the early stages of succession of coppice oak forest in Turkey.

Oak (*Quercus* spp.) is an important genus for Turkish forestry. In the past, most oak forests were managed through coppice cuts via clear-cuttings in 20-year rotations. The intensive use of oak forests under coppice management has caused long-term degradation in oak forest ecosystems. The Turkish General Directorate of Forestry has abandoned coppice forest management during the last decade, and now promotes conversion to high forest originating from seed. The new management regime positively contributes to ecosystem services such as carbon storage (Makineci *et al.* 2015) and arthropod diversity (Keten *et al.* 2015). However, impacts on the small mammal community are unknown.

In the current study, we hypothesized that *Apodemus* spp. richness and abundance at coppice-regenerated oak sites increased with stand age and varied by site. The objective is to relate the abundance of *Apodemus* spp. to stand type and to developing stage stand characteristics in coppice oak forest.

METHODS

Study area and sampling. The study was conducted on pure oak stands in northern Thrace, Turkey (figure 1). Elevation of stands varied from 125 – 680 m above sea level. The common oak species were sessile oak (*Quercus petraea* (Mattuschka) Liebl.), Hungarian oak (*Q. frainetto* Ten.) and Turkey oak (*Q. cerris* L.). The history of the rotations and the clear-cut schedules was unfortunately unknown for the study sites managed as coppice stands (Keten *et al.* 2015).

At five sites (Catalca, Demirkoy, Igneada, Kirklareli and Vize), sample plots (100 x 100 m) belonging to three development stages (A, B and C) were sampled. Stands were classified by stages of development; "A" (0 – 8 cm), "B" (9 – 20 cm) and "C" (21 – 36 cm) mean diameter at breast height (DBH) scales, using the categorization values of the Ministry of Forest and Water Affairs of the Republic of Turkey (Keten *et al.* 2015). We selected a total of 43 plots that represented the five study areas. Sampling was conducted on sample plots from each site, from three stand types, which were replicated three times, except for Catalca where stand-types "A" and "C" were only sampled two times. Plot coordinates and elevation were determined by Global Positioning System (Garmin GPS60). Tree species and tree density were determined by counting trees from a 20 x 20 m subplot located in the center of the 100 x 100 m plot (Keten *et al.* 2015). We measured DBH and crown diameter of trees. DBH was measured using tree calipers. Crown diameter was measured using the diametric projection of the tree crown on the forest floor by a measuring tape. Soil pH was determined using a pH meter (Hanna model HI221). Forest floor mass, which consisted of shed vegetation parts (litter, decomposing litter and humus layers) and understory mass, which was comprised of herbaceous plants (0 – 80 cm tall vegetation) were also recorded. Five samples were collected for understory and forest floor in each plot. Understory samples were taken by cutting above-ground parts of all herbaceous mass in a 1 m^2 area and the samples of the forest floor were taken from 0.25 m^2 area by collecting all the forest floor material over mineral soil. In the laboratory, understory and forest floor samples were dried to a constant mass at 70 ˚C and weighed (Makineci *et al.* 2011).

Apodemus spp. were sampled in July 2009 at each of the 43 plots using a box-style live trap model SH301 produced by Teknikturk Company. Each 100 x 100 m plot was divided into 16 subplots (25 x 25 m) and enumerated for allocation of sampling points (figure 2). The traps were

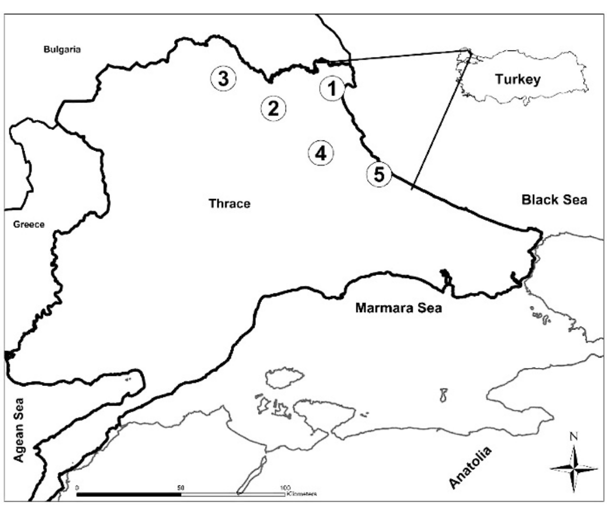

Figure 1. Sampling sites (circle); (1) Igneada, (2) Demirkoy, (3) Kirklareli, (4) Vize and (5) Catalca, Turkey.

Sitios de muestreo (círculos); (1) Igneada, (2) Demirkoy, (3) Kirklareli, (4) Vize y (5) Catalca, Turquía.

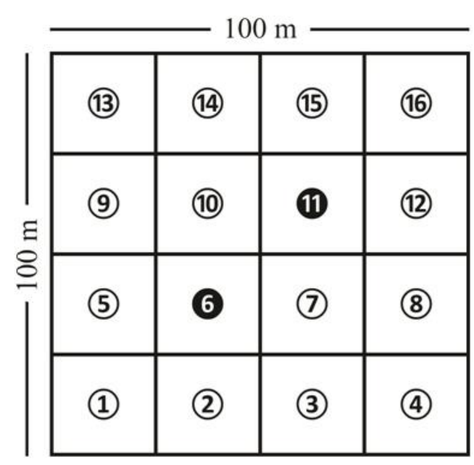

Figure 2. Sampling plots divided into 16 subplots (25 x 25 m). Open circle indicates sampling subplots, and solid circle indicates non-sampling subplots.

Parcelas de muestreo divididas en 16 subparcelas (25 x 25 m). Círculos blancos: subparcelas de muestreo; círculos negros: subparcelas sin muestreo.

placed in the center of each subplot, and checked 24 h later, except at numbers 6 and 11 as a different trap type was used for insectivorous species. A total of 602 trap nights were sampled. We used crushed peanuts as bait. Species were identified based on well-known color and morphological differences.

Data analyses. We calculated the number of mice captured per trap night and used these values for analyses. Data were transformed by Log (number of specimens + 1) for analyses because they were not normally distributed. The one – way analysis of variance (ANOVA) was used to compare number of *Apodemus* spp. among sampling sites (Catalca, Demirkoy, Igneada, Kirklareli and Vize) and stand types ("A", "B" and "C"). Mean ($\bar{x}$) and standard error (SE) of stand characteristics (tree density, DBH, crown diameter, soil pH, forest floor mass, understory mass, elevation, tree diversity) were determined for each stand type. Tree diversity was calculated using the Shannon-Wiener (H`) biodiversity index for woody plant species in each plot. *Apodemus* spp. abundance was examined in relation to habitat characteristics using the simple linear regression analysis. The canonical discriminant analysis (CDA) was used to differentiate stand types based on all stand characteristics measured in the study. The first axis (Can1) was compared with stand types using ANOVA. Following a significant ANOVA, we used Tukey HSD as a mean separation technique. Significance was set at $\alpha = 0.05$ level. All tests were conducted using Program R Gui version 3.1.1 (R Development Core Team 2015).

RESULTS

We captured 75 individuals of *Apodemus* spp. (0.125 ± 0.013 mice/trap night), comprised of *A. sylvaticus* (4), *A. flavicollis* (69), *A. agrarius* (1) and unknown (1), from 602 trap nights in 43 plots. The number of specimens was significantly influenced by stand type ($F_{2,40} = 3.55$, $P = 0.038$) (figure 3), though not by sampling site ($F_{4,38} = 2.37$, $P = 0.070$). *Apodemus sylvaticus* was only recorded in young stands measuring < 10 cm DBH.

Based on stand types, DBH, crown diameter, forest floor mass and number of trees per hectare varied, though elevation, soil pH, understory mass and H` did not (table 1). The number of *Apodemus* specimens was positively influenced by DBH ($y = 0.18 + 0.015x$, $R^2 = 0.21$, $P = 0.002$) and forest floor mass ($y = 0.005 + 0.00005x$, $R^2 = 0.22$, $P = 0.001$). Effects of the other stand characteristics (understory, H`, crown diameter and number of tree per hectare) on the number of specimens were not clear (table 2). The canonical discriminant analysis showed a grouping by stand type. Group means were significantly different (Wilks' Lambda = 0.005; F = 686.1; $P < 0.001$). The first canonical dimension accounted for most (97.8 %) of the variation (figure 4). The first five factors were DBH ($R^2 = 0.94$, $F_{2;40} = 295$, $P < 0.001$), crown diameter ($R^2 = 0.74$, $F_{2;40} = 56.8$, $P < 0.001$), forest floor mass ($R^2 = 0.67$, $F_{2;40} = 39.9$, $P < 0.001$), number of *Apodemus* specimens ($R^2 = 0.15$, $F_{2;40} = 3.55$, $P = 0.038$) and number of trees ($R^2 = 0.13$, $F_{2;40} = 3.11$, $P = 0.055$).

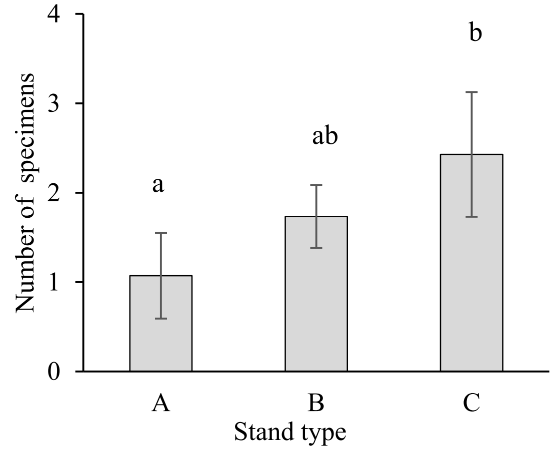

Figure 3. Differences in mean levels with standard error (SE) of number of *Apodemus flavicollis*, *A. sylvaticus* and *A. agrarius* specimens in stand types ["A" (0–8 cm), "B" (9–20 cm) and "C" (21–36 cm) mean diameter at breast height (DBH)].

Diferencias en los niveles medios y error estándar del número de individuos de *Apodemus flavicollis*, *A. sylvaticus* y *A. agrarius* en tipos de rodales [DAP: "A" (0–8 cm), "B" (9–20 cm) y "C" (21–36 cm)].

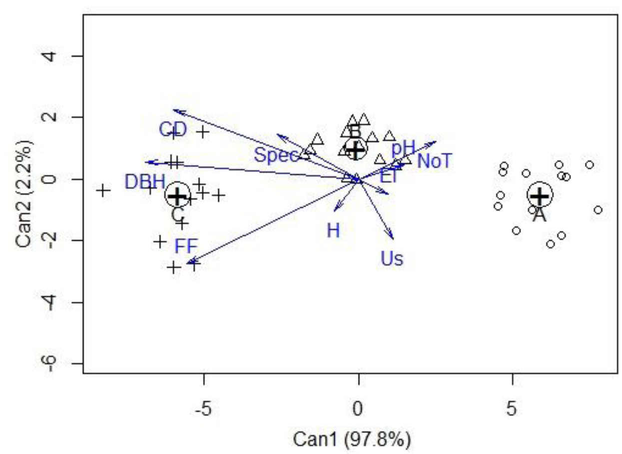

Figure 4. Canonical discriminant analysis of stand types [("A" (0–8 cm), circle; "B" (9–20 cm), triangle; and "C" (21–36 cm), plus] for stand characteristics (DBH; diameter at breast height, FF; forest floor mass, CD; crown diameter, Spec; number of specimens, H; tree Shannon-Wiener diversity index, Us; Understory mass, El; elevation, NoT; number of tree per hectare and pH; soil pH).

Análisis discriminante canónico de rodales tipo [("A" (0–8 cm), círculo; "B" (9–20 cm), triángulo, y "C" (21–36 cm), cruz] para características de los rodales (DBH: DAP; FF: masa de mantillo; CD: diámetro de copa; Spec: número de individuos; H: índice de diversidad de Shannon-Wiener para árboles; Us: masa de sotobosque; El: elevación; NoT: número de árboles por hectárea; pH: pH del suelo).

Table 1. Mean ($\bar{x}$) and standard error (SE) of eight stand characteristics for stand type ["A" (0–8 cm), "B" (9–20 cm) and "C" (21–36 cm) mean diameter at breast height (DBH)]. The same lowercase letter following the SE within a column indicates no significant difference based on Tukey HSD ($P > 0.05$).

Promedio ($\bar{x}$) y error estándar (SE) de ocho rodales característicos [DAP: "A" (0–8 cm), "B" (9–20 cm) y "C" (21–36 cm)]. La misma letra minúscula dentro de cada columna indica que no hay diferencia significativa según Tukey ($P > 0,05$).

Stand type	No of trees ha^{-1}	DBH (cm)	Crown diameter (cm)	Soil pH	Forest floor (kg ha^{-1})	Understory (kg ha^{-1})	Elevation (m)	Tree diversity
	$\bar{x}$ ± SE	$\bar{x}$ ± SE	$\bar{x}$ ± SE	$\bar{x}$ ± SE	$\bar{x}$ ± SE	$\bar{x}$ ± SE	$\bar{x}$ ± SE	$\bar{x}$ ± SE
A	1,056 ± 222 a	2.8 ± 0.7 a	73 ± 25 a	5.9 ± 0.2 a	4,795 ± 439 a	1,103 ± 244 a	416 ± 74 a	0.493 ± 0.14 a
B	938 ± 112 a	13.3 ± 0.6 b	384 ± 38 b	5.8 ± 0.2 a	6,100 ± 271 b	777 ± 157 a	363 ± 56 a	0.478 ± 0.10 a
C	607 ± 68 b	21.8 ± 0.5 c	516 ± 36 c	5.6 ± 0.2 a	9,844 ± 630 c	870 ± 129 a	346 ± 63 a	0.592 ± 0.08 a

Table 2. Results of the regression analysis between *Apodemus* spp. abundance and stand characteristics (No. of trees, DBH, crown diameter, soil pH, forest floor mass, understory mass, elevation, biodiversity index). Significance level of the statistic tests: * = $P < 0.05$; ** = $P < 0.01$; ns = not significant.

Resultados del análisis de regresión entre la abundancia de *Apodemus* spp. y características de los rodales (número de árboles, DAP, diámetro de copa, pH sel suelo, masa de mantilla, masa de sotobosque, elevación, índice de biodiversidad). Nivel de significancia en los análisis estadísticos: * = $P < 0,05$; ** = $P < 0,01$; ns = no significativo.

Stand characteristics	R^2	F-value	*P*
Number of trees ha^{-1}	0.06	2.72	ns
DBH (cm)	0.21	11.10	0.002**
Crown diameter (cm)	0.13	6.33	0.016*
Soil pH	0.13	6.02	0.018*
Forest floor (kg ha^{-1})	0.22	11.72	0.001**
Understory (kg ha^{-1})	0.02	0.086	ns
Elevation (m)	0.03	1.15	ns
Biodiversity index of tree	< 0.01	0.04	ns

DISCUSSION

Apodemus spp. abundance, driven primarily by *A. flavicollis*, increased with forest age in coppice oak forests. In coppice woodland, *A. sylvaticus* appeared in clear-cut and young woodlands, whereas *A. flavicollis* occurred most often in mature and old woodlands (Capizzi and Luiselli 1996). Similar to our results, others have found that *A. flavicollis* are generally more common in Thrace and Anatolia (Yigit *et al.* 2002, Colak *et al.* 2007, Krystufek and Vohralik 2007), and in mature forests than other *Apodemus* spp. (Pupila and Bergmanis 2006). In general there is a change in community dominance from habitat generalists to forest specialists during succession (Pinotti *et al.* 2015). However, it is not a universal principle that small mammals increase in abundance in older successional forest stages (Kirkland Jr. 1977).

Older oak forests, which resulted in higher numbers of *Apodemus flavicollis*, exhibited common characteristics of older stands including trees with larger average DBH, superior crown diameter, higher forest floor mass and lower tree density. In many deciduous forests, temporal and spatial abundance of mice is influenced by seed supply (Angelstam *et al.* 1987, Montgomery *et al.* 1991, Fernandez *et al.* 1996). Although acorn productivity varies by oak species, it generally increases by middle age (DBH 50–80 cm), then decreases slightly (Auchmoody *et al.* 1993, Johnson 1994). In this current study, the amount of acorns was not measured, but it is surmised that it was the lowest in young stands and the highest in mature stands as demonstrated by the positive relation to trees with larger DBH and superior crown diameter and lower tree density. Others have also found that *Apodemus* spp. are related to a high level of canopy cover (Marsh and Harris 2000). *Apodemus* spp. use burrows and tunnel systems to nest, store food and survive harsh seasons or conditions below ground (Jennings 1975). The high forest floor biomass helps perpetuate *Apodemus* spp. abundance. We conclude that the increased number of *Apodemus* spp. specimens, particularly *A. flavicollis*, with developing stage stands was most likely explained by increased forest floor mass and acorn abundance.

Although silvicultural practices can negatively affect *Apodemus* spp. abundance (Rhim and Lee 2001), conversion of coppice oak forests to high forest appears generally beneficial for *A. flavicollis*. Ensuring the continued existence of *Apodemus* spp. contributes to overall biodiversity conservation. Abandonment of the coppice oak practices, in the Thrace, may positively affect the local abundance of *Apodemus* spp., particularly *A. flavicollis*. Our results suggest that common woodland management practices, such as maintaining low disturbance areas and encouraging a diverse range of native tree and shrub species will help ensure survival of *A. flavicollis*. Further research is necessary to determine impacts of various forest management practices on *A. sylvaticus* and *A. agrarius*.

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