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Arthropod diversity in pure oak forests of coppice origin in northern Thrace (Turkey)

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Oak (*Quercus* spp.) forests are among the most important forest types in Turkey. In the past, oak forests were managed through coppice clear-cutting, but in recent decades they have mostly been converted to high forest. This study was aimed at explaining how arthropod diversity is affected during conversion from coppice to high oak forest and during the early stages of coppice succession. We tested the hypothesis that arthropod richness, abundance and diversity in coppice oak sites varied according to stand age and a number of other forest characteristics. Arthropod communities were sampled in 50 plots using four different methods: pitfall traps, sweep nets, sticky cards and cloth shaking. A total of 13 084 individuals were collected and classified into 193 Recognizable Taxonomic Units (RTUs), with the most RTUs and the greatest number of specimens captured by sweep netting. We identified 17 taxa within RTU's with more than 1% of the captured arthropods, which constituted 75% of the total specimens. The number of RTUs varied significantly according to trap type. Arthropod richness and Shannon-Wiener biodiversity index (*H'*) increased with elevation and precipitation. In young (1-40 yrs-old) and middle-aged (41-80 yrs) stands, arthropod biodiversity was not significantly affected by stand type, but slightly increased with diameter at breast height and tree height. Forest characteristics, such as the litter layer, understory and crown diameter, weakly influenced arthropod richness and abundance. Cluster analysis revealed that stand types and trap types differed taxonomically. Principal component analysis showed that stand types were clearly separated by the stand parameters measured. Insect families (Formicidae, Thripidae, Lygaeidae, Dolichopodidae, Luaxanidae, Cicadellidae and Ichneumonidae) could potentially be used as indicators of coppice oak conditions. As the coppice oak changes to mature forest, further studies are needed to better assess the relation between arthropods, forest types and structural characteristics of stands.

Keywords: Elevation, *Quercus*, Recognizable Taxonomic Units, Trap Types, Stand Types, Stand Characteristics

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Introduction

Turkey is one of the world's richest countries in terms of the variety of oak species and their extent. Oak forests cover vast areas in Northern Thrace (European Part of Turkey): 656 004 ha, or 27.7% of the entire land area, of which oak forests make up 71.7% of forest lands (Makineci et al. 2011). In the past, most oak forests were managed as coppice *via* clear cuttings on 20-year rotations. However, the intensive use of the forest led to its long-term degradation. Therefore, Turkish General Directorate of Forestry abandoned such practice in the last decade, and now promotes conversion to high forest and natural regeneration from seeds.

Arthropods are often used as ecological indicators of ecosystem integrity (King et al. 1998, Tscharntke et al. 1998, Rainio & Niemelä 2003, Langor & Spence 2006, Maleque et al. 2009). They play essential roles in ecosystems such as pollination, seed dispersal, nutrient cycling, and they serve as predators of pests and prey for valued vertebrates (Engelmann 1961, van Straalen 1998). Arthropods also have short generation times and respond quickly to ecological changes (Work et al. 2002). Habitat structure influences arthropod diversity and abundance (Spitzer et al. 2008). In general, systems that are more diverse, permanent, isolated and managed with low intensity are associated with high arthropod community diversity (Akbulut et al. 2003). Increasing plant diversity has been suggested as a means of increasing insect diversity (Symstad et al. 2000) and thus lowering insect herbivore damage through decreased host plant density, increased interspecific competition among pest and non-pest species and improved natural enemy communities (Stamps & Linit 1998).

Arthropod species richness generally increases with stand age (Siemann et al. 1999, Bolger et al. 2000), and richness and density of herbivorous insects are influenced by forest age (Jeffries et al. 2006). However, there is limited knowledge about arthropod diversity during the conversion of coppices to high oak forests and the early stages of succession of coppice oak forests in Turkey. In the present study, we hypothesized that arthropod richness, abundance and diversity at coppice oak sites increased with stand age. The objectives of our study were to: (1) identify differences in forest characteristics among forest stand types; (2) characterize differences in arthropod richness, diversity, and abundance among forest stand types, and (3) relate invertebrate taxa to method of capture and to forest stand characteristics.

Materials and methods

Study sites

This study was carried out in pure oak stands growing at five different sites (Catalca, Demirkoy, Igneada, Kirklareli and Vize) in the Northern Thrace, Turkey (Fig. 1). Sites were coppice-originated forests, but currently are being converted to high forest. Climate (precipitation, temperature and wa-

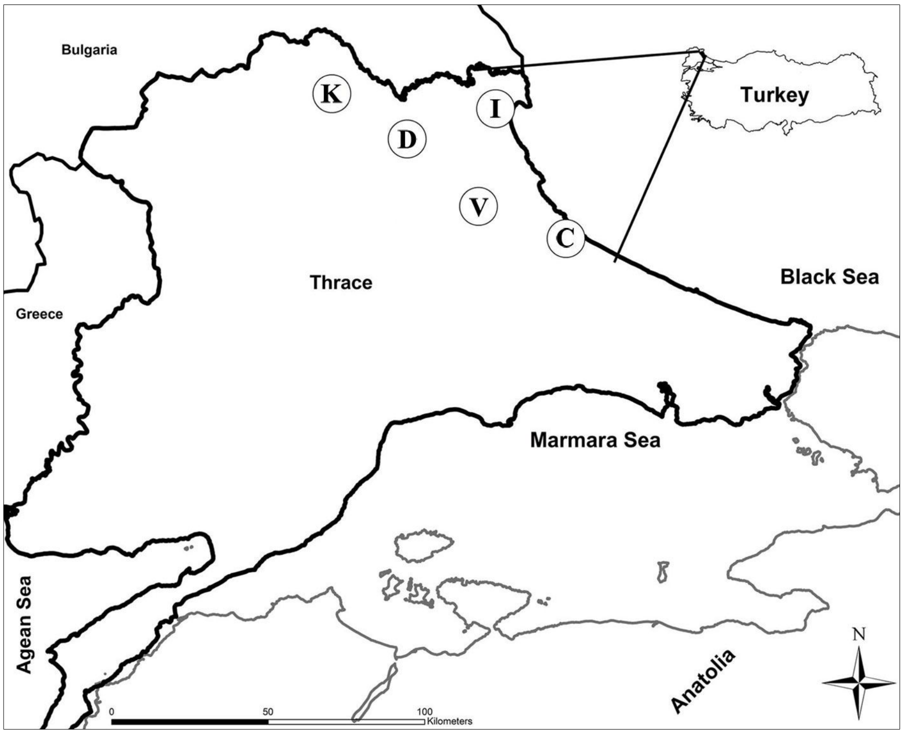

Fig. 1 - Map of Northern Thrace (Turkey) with the location of sampling sites (circles). (C): Catalca; (D): Demirkoy; (I): Igneada; (K): Kirklareli; (V): Vize.

ter deficit) and elevation varied among areas (Tab. 1). Common oak species are Sessile oak (*Quercus petraea* (Mattuschka) Liebl.), Hungarian oak (*Q. frainetto* Ten.) and Turkey oak (*Q. cerris* L. - Makineci et al. 2011). The previous history of rotations and the clear-cut schedules were unfortunately unknown for coppices at the study sites.

Stand formations at each study plot were identified through forest management plans and field studies. Stands were classified by mean diameter at breast height (DBH) as: "a" 0-8 cm; "b" 9-20 cm; and "c" 21-36 cm; or as degraded stands ("Dg") with a canopy closure of less than 10%, following categories used by the Ministry of Forestry and Water Affairs of the Republic of Turkey. Stand ages were determined according to Leatherberry et al. (2006).

Data collection and arthropods sampling

For faunal studies, we selected a total of 50 plots distributed across different elevations (10-800 m), slopes (0-90 %) and locations (Fig. 1, Tab. 1). Sampling was conducted in four different stand types ("a", "b", "c" and "Dg") at each of the five sampling sites. In each stand, sampling was replicated three times except for degraded stands ("Dg"), which only had one replicate. Each plot was 100 × 100 m, with plot coordinates and elevation determined by GPS. Tree species, number of tree per hectare and percentage of snags were determined by counting trees from a 20 × 20 m centrally-located sub-plot. We measured DBH, tree height and crown diameter of trees. DBH was measured using tree calipers and tree height with an altimeter. Crown diameter was measured using the diametric projection of the tree crown on the litter by a measuring tape. Litter mass, which consisted of shed vegetation parts, and understory mass, which was comprised of herbaceous plants, were also recorded. Five samples were collected from the understory and litter in each plot. Understory samples were taken by cutting above-ground parts of all herbaceous mass in a 1 m^2 area, while samples of the litter were taken from a 0.25 m^2 (50 × 50 cm) area by collecting all litter over mineral soil. In the laboratory, understory and litter samples were dried at 70 °C for > 24 h to a constant mass and weighed (Makineci et al. 2011).

Arthropods were sampled in July 2009 at each of the 50 plots using four different trapping methods: pitfall traps (Work et al. 2002), sweep netting (Siemann et al. 1998), sticky cards (Hamilton et al. 2012) and cloth shaking (Akbulut et al. 2003). Each 100 × 100 m plot was divided into 16 subplots (25 × 25 m) and enumerated for allocation of sampling points. For pitfall traps, four holes, 15 cm in diameter and 15 cm in depth, were made in the ground. Pitfall traps (plastic cups) were placed and checked 24 h later for soil-dwelling arthropods. Traps were set at equal distances along the diagonal at subplots numerated as 1, 6, 11 and 16 in each sample plots and filled to a depth of 2 cm with ethylene glycol as a preservative. Three of the 200 cups were damaged by wild boar (*Sus scrofa*). Twenty sweeps with a sweep net were collected from two randomly chosen subplots; these samples were used to evaluate the diversity and number of arthropods present in ground vegetation. Yellow sticky cards, 15 × 30 cm, were hung on a randomly selected tree in subplots 7 and 10, placed at approximately mid-canopy height for canopy arthropods and removed 24 h later. Cloth-shaking sampling was used to sample arthropods in the oak canopies. A tree in each of two randomly selected subplots was shaken three times over a piece of cloth (3 × 3 m), using the branches rather than the stem for trees thicker than 5 cm DBH. Arthropods falling on the cloth were collected and preserved.

Data analyses

We determined the number of trees per hectare, average DBH, height and crown diameter in the sampling plots. To test for differences between forest variables, including litter mass (kg ha^{-1}), understory mass (kg ha^{-1}), tree density (no ha^{-1}), percentage of snags at sampling sites (Catalca, Demirkoy, Igneada, Kirklareli, Vize), and stand types ("a", "b", "c" and "Dg"), we used one-way analysis of variance (ANOVA). Collected arthropods were counted and categorized into Recognizable Taxonomic Units (RTUs), based on easily recognized features which can be used for rapid assessment of biodiversity (Oliver & Beattie 1993). We calculated diversity index (Shannon-Wiener H') based on RTUs. ANOVA was used to compare the number of RTUs, H' and number of specimens on sampling sites to stand types. Because of the high degree of variation in arthropod densities, significance was set at $\alpha = 0.10$. Separate regressions were performed

Tab. 1 - Main characteristics of the oak sampling sites (source: Makineci et al. 2011).

Sampling Site	Mean Elevation (m)	Min-max slope (%)	Mean annual precipitation (mm)	Average annual temp. (°C)	Annual water deficit (mm)
Catalca (C)	290	0-20	844	14	212
Demirkoy (D)	680	10-60	1053	11	84
Igneada (I)	125	0-90	867	13	181
Kirklareli (K)	500	0-50	550	14	274
Vize (V)	320	0-45	720	12	244

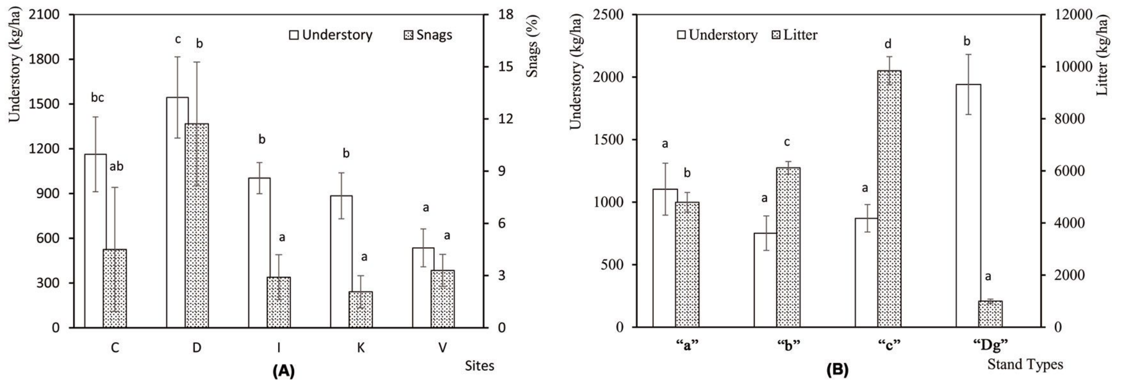

Fig. 2 - (A) Mean understory mass and percentage of snags at the five sampling sites analyzed. (C: Catalca; D: Demirkoy; I: Igneada; K: Kirklareli; V: Vize). (B) Mean understory mass and litter mass in the 4 stand types analyzed. ("a": mean DBH 0-8 cm; "b": 9-20 cm; "c": 21-36 cm; "Dg": degraded stands with a canopy closure < 10%). Error bars represent the standard deviation. Different letters among bars indicate significant differences after ANOVA (p<0.05).

to examine the relationship between percentage of snags and total arthropods, the litter mass and soil-dwelling arthropods, and between understory mass and arthropods present in the understory. We determined taxa within RTUs that comprised more than 1% of the total, which in turn constituted 75% of all specimens. Each group of RTU specimens were compared between stand types and trapping method. We also made use of Akaike's Information Criterion (AIC) to describe the best model determined by the smallest AIC_c value (Burnham & Anderson 2002) with *H′* and DBH, height and crown diameter related to stand type. Cluster analysis and analysis of similarity (ANOSIM) was used to categorize sampling plot and trap types by RTU, using Ward's linkage and Bray-Curtis distance metrics. Principal component analysis (PCA) was used to differentiate stand types based on all parameters measured in the study. To determine the degree of importance for each parameter in the ordination model, a Pearson's (r) correlation analysis was conducted between variables. All tests were carried out using the software package RGui version 3.0.2 (R Development Core Team 2013).

Results

Stand characteristics

Three oak species (Sessile oak, Hungarian oak and Turkey oak) were present in the sampling plots. Sessile oak was the most common species at all sites except at Igneada, where Hungarian oak was the most prevalent species. Although Sessile oak was dominant in Demirkoy and Catalca, the other oak species also were prevalent in Vize and Kirklareli. Additional forest tree species were ash (*Fraxinus excelsior* L., *F. ornus* L.), Oriental beech (*Fagus orientalis* Lipsky), maple (*Acer campestre* L., *A. platanoides* L.), hornbeam (*Carpinus betulus* L., *C. orientalis* Mill.). Fruit-bearing shrubs were also recorded, such as rowan (*Sorbus aucuparia* L., *S. domestica* L., *S. torminalis* L.), common hawthorn (*Crataegus monogyna* Jacg.), wild plum (*Prunus avium* L., *P. divaricate* Ledep., *P. spinosa* L.), dogwood (*Cornus mas* L.), wild apple (*Malus* sp.) and medlar (*Mespilus germanica* L.). The average age of trees in the stand type "a" was 13 ± 5 years, 63 ± 8 in type "b" and 76 ± 15 in type "c". Stand type "a" was categorized as "young" (1-40 years old), while "b" and "c" as "middle-aged" (41-80 years old).

The understory mass and the percentage of snags were significanty different among sampling sites ($F_{[4, 45]}$ = 3.54, P = 0.014 and $F_{[4, 45]}$ = 2.83, P = 0.036, respecively), while no differences were detected in litter mass among sites ($F_{[4, 45]}$ = 0.14, P = 0.967). The understory and snags were most abundant in Demirkoy (Fig. 2a). Differences among stand types were significant for understory ($F_{[3, 46]}$ = 4.95, P = 0.005) and litter ($F_{[3, 46]}$ = 52.82, P <0.001), but not for snags ($F_{[3, 46]}$ = 1.01, P = 0.398). Litter mass was highest in "c" stands, and the understory mass was greatest in "Dg" stands (Fig. 2b). Number of trees per hectare was significantly different ($F_{[3, 46]}$ = 5.135, P = 0.004) among stand types. The standard deviation was high in young stands, and decreased with age. DBH ($F_{[3, 46]}$ = 198, P <0.001), height ($F_{[3, 46]}$ = 92.2, P <0.001) and crown diameter ($F_{[3, 46]}$ = 40.9, P <0.001) increased with age (Fig. 3a, Fig. 3b).

Arthropod data

In total, arthropod sampling caught 13 084 individuals of 193 RTUs from the four combined sampling methods (Tab. 2). The num-

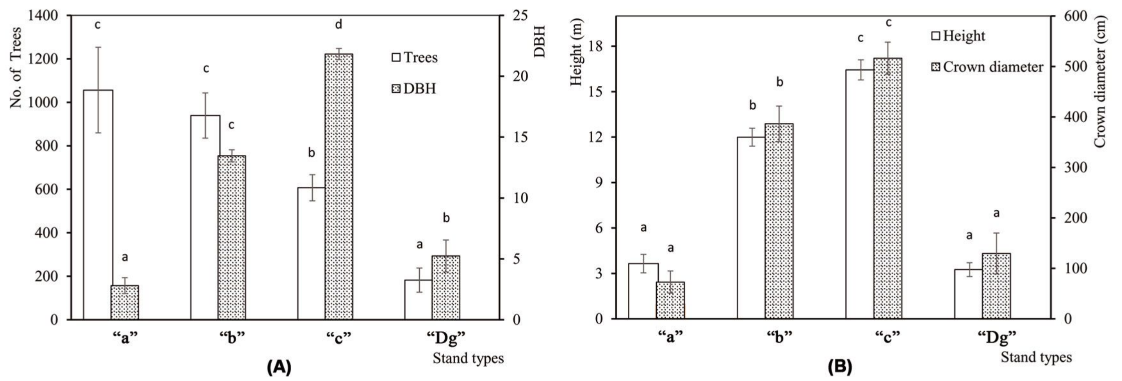

Fig. 3 - Mean structural characteristics of the four stand type classes analyzed. (A) Mean number of trees per hectare (Trees) and diameter at breast height (DBH). (B) Tree height and crown diameter. ("a"): mean DBH 0-8 cm; ("b"): mean DBH 9-20 cm; ("c"): mean DBH 21-36 cm; ("Dg"): degraded stands with a canopy closure < 10%. Error bars represent the standard deviation. Different letters among bars indicate significant differences after ANOVA (p<0.05).

Tab. 2 - The number of arthropod Recognizable Taxonomic Units (RTU's) and individuals (in parentheses) collected by the different sampling methods.

Trap type	Number of traps	No. of RTUs (max)	No. of specimens (max)	Means of Specimens ± SE
Pitfall Trap (Pt)	197	46 (7)	3783 (461)	19.20 ± 2.79
Sweepnet (Sw)	100	143 (32)	4833 (148)	48.33 ±3.53
Sticky Trap (St)	100	98 (26)	4062 (187)	40.62 ±3.25
Shaking (Sc)	100	48 (7)	406 (10)	4.06 ±0.23
Total	497	193	13084	26.33 ± 2.09

ber of RTUs ($F_{[3, 493]}$ = 73.31, P <0.001) and the number of specimens ($F_{[3, 493]}$ = 531.8, P <0.001) varied according to trapping methods. Most taxa were captured with sweepnets, and most specimens with sticky traps (Fig. 4a). The ANOVA revealed a significant influence of the sampling site on the number of RTUs ($F_{[4, 45]}$ = 10.56, P <0.001) and *H′* ($F_{[4, 45]}$ = 2.60, P = 0.048), but not on the number of specimens ($F_{[4, 45]}$ = 1.51, P =

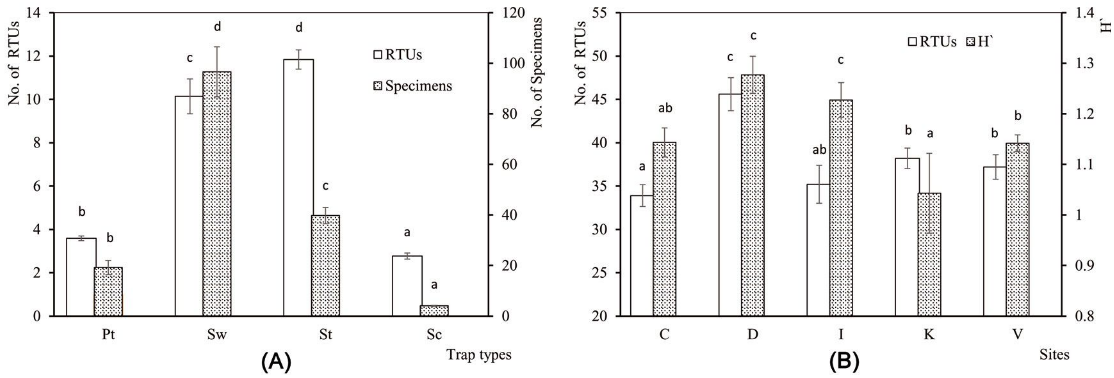

Fig. 4 - Relationships between species characteristics, trap types and sampling sites. (A) Mean number of Recognizable Taxonomic Units (RTUs) and mean number of specimens collected by different trap types (Pt: Pitfall trap, Sw: Sweepnet, St: Sticky trap, Sc: Shaking). (B) Mean number of RTUs and Shannon-Wiener index (*H′*) across sampling sites (C: Catalca, D: Demirkoy, I: Igneada, K: Kirklareli, V: Vize). Error bars represent the standard deviation. Different letters among bars indicate significant differences after ANOVA (p<0.05).

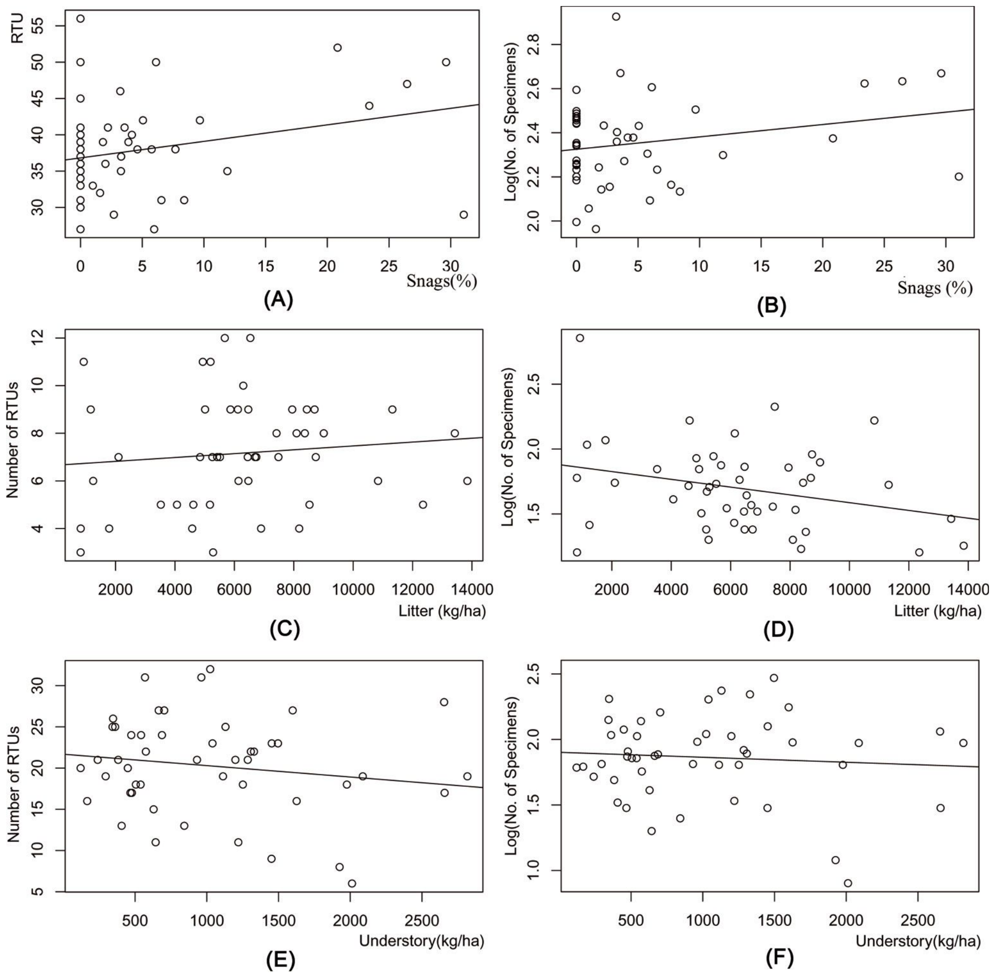

Fig. 5 - Results of the regression analysis between arthropod diversity and stand structural characteristics. (A): Number of Recognizable Taxonomic Units (RTU) *vs.* percentage of snags; (B): number of specimens (log) *vs.* percentage of snags; (C): number of RTU (based on pitfall trapping only) *vs.* litter mass; (D) number of specimens (log) from pitfall trapping only *vs.* litter mass; (E): number of RTU (based on sweepnet sampling only) *vs.* understory mass; (F); number of specimens (log) from sweepnet sampling only *vs.* understory mass.

0.214). *H′* was higher in Demirkoy and Igneada and more taxa were counted in Demirkoy (Fig. 4b). Based on the results of multiple regression analyses, elevation (*E*) and precipitation (*Pr*) significantly affected the number of RTUs (y = 28.65 + 0.019 E + 0.002 Pr, R^2 = 0.41, P <0.001), the number of specimens (y = 187.62 + 0.224 E - 0.028 Pr, R^2 = 0.14, P = 0.036) and *H′* (y = 0.819 + 0.00014 E + 0.00035 Pr, R^2 = 0.18, P < 0.001).

In the pitfall samples, the number of RTUs (y = 36.82 + 0.228x, R^2 = 0.074, P <0.001) and the number of specimens (y = 2.325 + 0.006 x, R^2 = 0.055, P <0.001) was positively influenced by the percentage of snags (Fig. 5a, Fig. 5b). There was a weak positive relation between the litter layer mass and the number of RTUs (y = 6.658 + 8.10^{-5} x, R^2 = 0.012, P <0.001), and a weak negative relation between litter layer mass and the number of specimens (y = 1.886 – 3.10^{-5} x, R^2 = 0.078, P<0.001 - Fig. 5c, Fig. 5d). Also, in the sweep net samples, there was no clear relationship between understory mass and the number of RTUs (y = 21.683 – 0.0014 x, R^2 = 0.026, P <0.001), or with understory mass and number of specimens (y = 1.902 – $3 \cdot 10^{-5}$ x, R^2 = 0.006, P <0.001 - Fig. 5e, Fig. 5f).

Stand types did not significantly differ in their diversity indices ($F_{[3, 46]}$ = 0.42, P = 0.743), the number of RTUs ($F_{[3, 46]}$ = 0.446, P = 0.722) or in the number of specimens ($F_{[3, 46]}$ = 0.580, P = 0.631). The relationship between DBH and RTU richness was weak, but positive (y = 37.75 + 0.016 x, R^2 = 0.003, P <0.001), while that between DBH and the number of specimens was weakly negative (y = 263.23 – 1.16 x, R^2 = 0.005, P <0.001). The best predictive models for the Shannon-

Tab. 3 - AIC_c statistics of the 7 regression models for the prediction of Shannon-Wiener index (*H′*) of arthropod diversity using diameter at breast height (DBH), height and crown diameter of trees as predictors (n=50). Models are sorted from the lowest to the highest ΔAIC_c value. The total number of estimable parameters (K) and Akaike weights (w_i) are reported.

Model	DBH (cm)	Height (m)	Crown diameter (m)	K	AIC_c	ΔAIC_c	w_i	R^2
1	-	×	-	2	-30.090	0.000	0.3304	0.04
2	×	-	-	2	-29.732	0.358	0.2763	0.03
3	-	×	×	3	-27.903	2.187	0.1107	0.07
4	×	×	-	3	-27.873	2.217	0.1090	0.04
5	-	-	×	2	-27.276	2.814	0.0809	<0.01
6	×	-	×	3	-26.650	3.440	0.0591	0.04
7	×	×	×	4	-25.520	4.570	0.0336	0.07

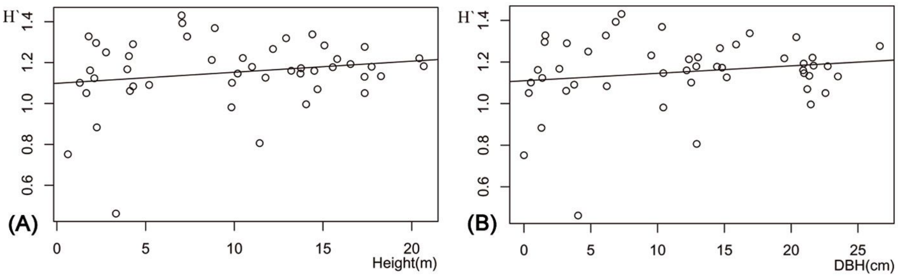

Fig. 6 - Variation of the Shannon-wiener index (*H′*) with (A) mean tree height and (B) mean diameter at breast height (DBH) of the sampled stands.

Tab. 4 - Number and percentage of specimens (with abundance > 1%) classified in each Recognizable Taxonomic Units (RTU) using the four sampling methods described (pitfall traps, sweepnet, sticky traps, shaking), and their average (± standard error) across the four stand type classes considered. ("a"): mean DBH 0-8 cm; ("b"): mean DBH 9-20 cm; ("c"): mean DBH 21-36 cm; ("Dg"): degraded stands with a canopy closure < 10%. All taxa varied significantly among trap types (P <0.01). (R): Correlation coefficient with the average diameter at breast height (DBH) of plots and the number of specimens. (P): p-value after ANOVA between stand types and the number of specimens. (*): p<0.1; (**): p<0.05).

RTU	Perc.(%)	No. of Specimens	Sampling Method				Stand type				R	P
			Pitfall Traps	Sweepnet	Sticky Traps	Shaking	"a"	"b"	"c"	"Dg"		
Araneae	13	1691	414	1070	78	129	29.5 ± 4.1	33.3 ± 5.0	37.5 ± 3.9	37.2 ± 5.4	0.17	0.475
Insecta	1	146	0	4	140	2	5.2 ± 2.7	2.5 ± 0.9	1.5 ± 0.7	1.6 ± 0.4	-0.13	0.830
Lepidoptera	1	136	0	119	12	5	2.3 ± 0.6	3.2 ± 0.7	3.0 ± 0.5	1.6 ± 0.4	0.15	0.509
Chalcidoidea	6	766	5	142	614	5	15.2 ± 2.3	15.7 ± 4.6	14.6 ± 2.7	16.8 ± 3.1	-0.04	0.985
Chrysomelidae	1	133	0	71	52	10	4.0 ± 1.3	1.9 ± 0.7	1.8 ± 0.6	3.4 ± 1.6	-0.25	0.459
Entomobryidae	2	249	249	0	0	0	4.4 ± 1.1	5.5 ± 1.3	5.8 ± 2.0	2.8 ± 1.2	0.20	0.686
Dolichopodidae	2	233	6	140	86	1	5.5 ± 2.5	3.2 ± 0.7	3.3 ± 0.7	10.6 ± 4.2	-0.15	0.072*
Luaxanidae	1	142	0	21	120	1	3.5 ± 0.5	2.8 ± 0.6	2.5 ± 0.6	1.8 ± 0.7	-0.08	0.517
Lygaeidae	2	272	2	267	0	3	17.0 ± 15.4	0.1 ± 0.1	0.5 ± 0.3	1.8 ± 1.3	-0.34	0.075*
Aphidae	2	227	0	164	56	7	3.7 ± 0.8	3.9 ± 1.1	6.6 ± 3.8	2.6 ± 1.7	0.17	0.639
Cercopidae	3	411	2	282	123	4	4.7 ± 1.5	8.4 ± 3.2	13.5 ± 5.6	2.4 ± 1.9	0.22	0.296
Cicadellidae	7	864	3	347	509	5	8.0 ± 1.4	18.3 ± 3.2	27.8 ± 7.0	10.4 ± 2.8	0.42	0.027**
Braconidae	3	446	0	54	392	0	9.4 ± 4.6	6.7 ± 2.3	12.7 ± 6.5	2.8 ± 1.1	0.10	0.640
Formicidae	23	2945	2673	166	15	91	57.6 ± 15.1	44.7 ± 13.1	36.7 ± 10.1	172.0 ± 130.1	-0.22	0.056*
Ichneumonidae	1	132	0	85	46	1	1.4 ± 0.3	3.1 ± 0.6	3.9 ± 0.7	1.0 ± 0.8	0.42	0.004**
Tettigoniidae	2	213	3	189	0	21	4.0 ± 1.0	4.6 ± 1.4	4.7 ± 1.4	2.8 ± 1.1	0.11	0.723
Thripidae	7	856	0	14	842	0	39.2 ± 14.6	9.9 ± 3.0	5.7 ± 1.0	7.0 ± 2.7	-0.38	0.076*
Others	25	3222	426	1698	977	121	-	-	-	-	-	-
Total	100	13084	3783	4833	4062	406	-	-	-	-	-	-

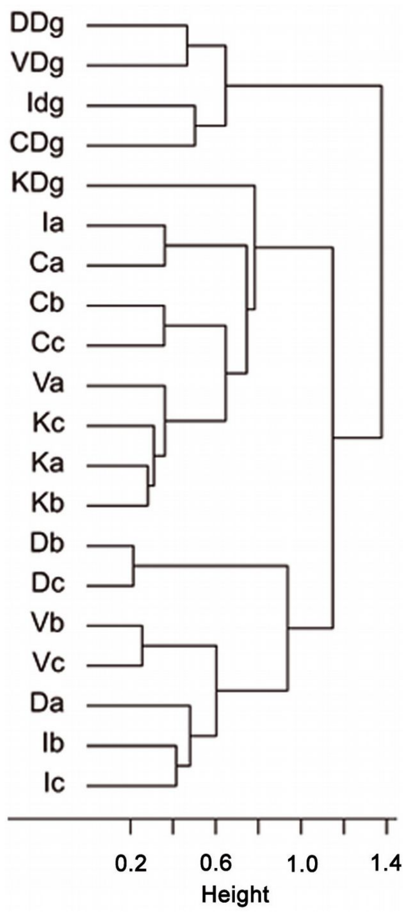

Fig. 7 - Cluster analysis of stand types based on the similarity of Recognizable Taxonomic Units (RTU) using Ward's linkage and Bray-Curtis distance metrics. The first letter of labels refers to sampling sites (C: Catalca; D: Demirkoy; I: Igneada; K: Kirklareli; V: Vize), the second letter refers to stand types ("a": mean DBH 0-8 cm; "b": mean DBH 9-20 cm; "c": mean DBH 21-36 cm; "Dg": degraded stands with a canopy closure < 10%).

Wiener index was determined based on the smallest AIC_c values. For AIC_c <2, these were $H' = 1.0987 + 0.0054 \cdot height$ and $H' = 1.1096 + 0.001 \cdot DBH$ (Tab. 3). The relation between arthropod H' and tree DBH and height was weak (Fig. 6a, Fig. 6b). Also, the composite model for Shannon-Wiener index was $H' = 1.10793 + 0.0018 \cdot DBH + 0.0051 \cdot height - 0.0067 \cdot crown\ diameter$. In the model, tree height (t_{49} = 22.92, P <0.001), DBH (t_{49} = 25.06, P <0.001) and the composite model (t_{49} = 19.46, P <0.001) were significant for H'.

Overall, seventeen taxa within RTUs were found to comprise more than 1% of the captured arthropods, corresponding to 75% of the total specimens. Each of the 17 taxa varied significantly based on trap type (P < 0.01 - Tab. 4). There was a mid-level positive relation between DBHs and number of specimens of Cicadellidae and Ichneumonidae (R = 0.42), and a mid-level negative relation between DBHs and number of specimens of Lygaeidae (R = -0.32) and Thripidae (R = -0.38). Significant differences among stand types were found for Dolichopodidae ($F_{[3, 46]}$ = 2.495, P = 0.072), Lygaeidae ($F_{[3, 46]}$ = 2.459, P = 0.075), Cicadellidae ($F_{[3, 46]}$ = 3.358, P = 0.027), Formicidae ($F_{[3, 46]}$ = 2.713, P = 0.056), Ichneumonidae ($F_{[3, 46]}$ = 5.051, P = 0.004) and Thripidae ($F_{[3, 46]}$ = 2.452, P = 0.076 - Tab. 4).

Cluster analysis of stand types based on RTUs formed three large clusters, showing that both sampling sites and stand types were significantly dissimilar (R = 0.15, P = 0.038 and R = 0.255, P = 0.001, respectively - Fig. 7), as well as trap types (R = 0.823, P <0.001 - Fig. 8). Results of the PCA based on 19 parameters (total number of RTU and total number of specimens across all trap types; number of RTUs and number of specimens within each trap type: pitfall trap, sweepnet, sticky trap and cloth shaking; H'; elevation; number of trees per ha; DBH; height; crown diameter; percentage of snags; litter mass; understory mass) showed a fairly good discrimination of stand types along the first two axes (Fig. 9), with significant differences among stand type classes ($F_{[3, 44]}$ = 4.43, P <0.001). The first principal compo-

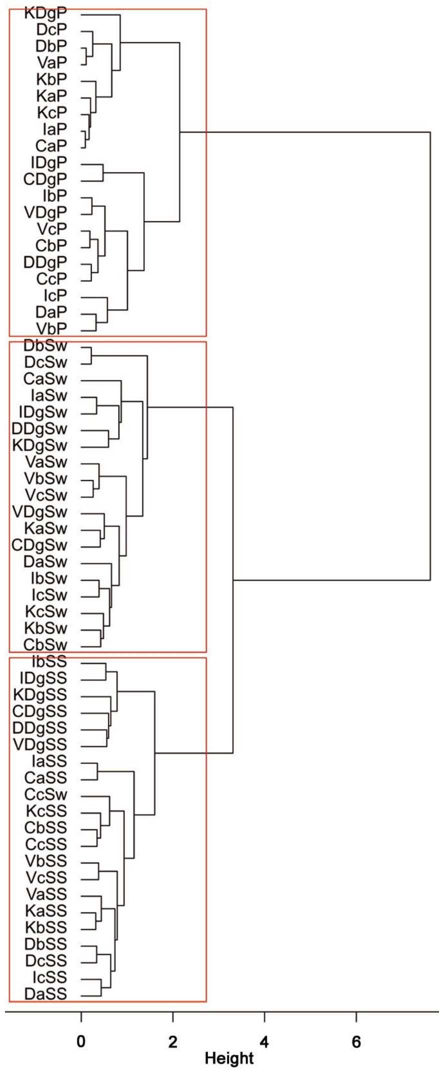

Fig. 8 - Cluster analysis of different sampling methods adopted at the different stand types and sampling sites, based on the similarityy of Recognizable Taxonomic Units (RTU) using Ward's linkage and Bray-Curtis distance metrics. The dendrogram indicate a greater separation between soil-dwelling arthropod composition and canopy or sub-canopy arthropod composition than between canopy and sub-canopy arthropod communities. The first letter of labels refers to sampling sites (C: Catalca; D: Demirkoy; I: Igneada; K: Kirklareli; V: Vize), the second letter refers to stand types ("a": mean DBH 0-8 cm; "b": mean DBH 9-20 cm; "c": mean DBH 21-36 cm; "Dg": degraded stands with a canopy closure < 10%), while the last letter(s) refers to the sampling method (P: Pitfall trap; Sw: Sweepnet; SS: Sticky trap and Shaking).

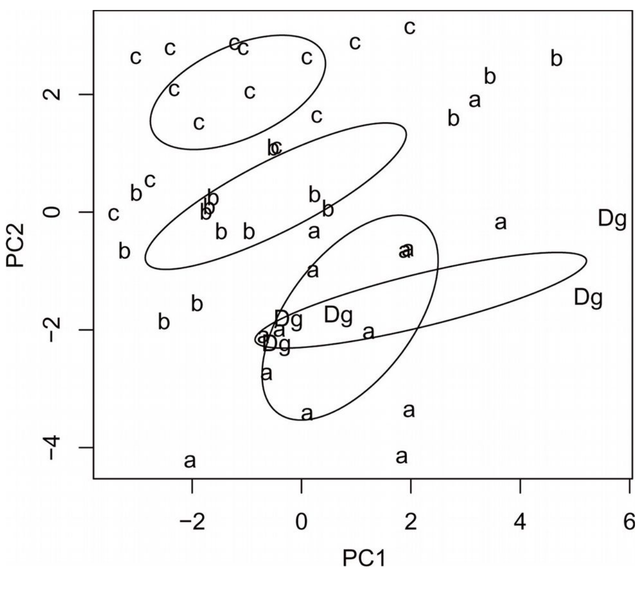

Fig. 9 - Results of the PC analysis of stand types ("a": mean DBH 0-8 cm; "b": 9-20 cm; "c": 21-36 cm; "Dg": degraded stands with canopy closure < 10%) based on the following variables: total number of RTU and total number of specimens across all trap types, number of RTUs and number of specimens within each trap type (pitfall trap, sweepnet, sticky trap and cloth shaking), H', elevation, number of trees, DBH, height, crown diameter, number of snags, litter mass and understory mass.

nent (PC1) accounted for approximately 27% of the total variation, and showed a high correlation with total number of RTUs (r = 0.73), RTUs richness in sticky trap sampling (r = 0.73), and elevation (r = 0.69). PC2 explained 21% of the total variation, and showed the highest correlations with DBH (r = 0.79), tree height (r = 0.72) and RTU in sweep net sampling (r = 0.71 - Fig. 9).

Discussion

Arthropod richness, diversity and composition were influenced by climate and elevation in Thrace. Indeed, species richness, number of specimens and biodiversity increased with elevation and precipitation. The observed increase in diversity with elevation may be due, in part, to the local covariation of such factors, as reported for many temperate and arid habitats (Sanders et al. 2003). Abundance of most arthropod taxa increased with elevation (Uetz et al. 1979). Some insect species increased their frequency with elevation up to 600-800 m, and then decreased in southwestern USA (McCoy 1990). In tropical forest, insect species richness, number of individuals and diversity increased up to 1000 m, and then declined (Wolda 1987).

Our results did not confirm that arthropod richness and biodiversity were specifically affected by stand types in young and middle-aged forests, but arthropod diversity, richness and the number of specimens did increase slightly with DBH. In oak forest, herbivore species richness and density correlated positively with forest age (Jeffries et al. 2006). In this study, DBH, height and crown diameter did impact on biodiversity, although crown diameter had the least influence.

Some arthropods are often used as bioindicators (King et al. 1998, Langor & Spence 2006, Maleque et al. 2009). For example, Formicidae have been used as bioindicators of ecological degradation, concomitant with decreasing litter and canopy (King et al. 1998), such as in our study. Using more than one taxon as an indicator of environmental conditions or biodiversity can be problematic, since a taxonomic group may behave differently from other groups (Finch 2005). However, several authors recommended the use of multiple taxonomic indicators as each species group is related with different habitat characteristics (Jonsson & Jonsell 1999). Our results showed that the density of Formicidae, Thripidae, Lygaeidae, Dolichopodidae and Luaxanidae declined, while the density of Cicadellidae and Ichneumonidae increased with forest age. Dolek et al. (2009) also found that Formicidae species decreased from pasture coppice oak to high forest in Germany. Although Araneae are often used as indicators (Platen 2003, Coote et al. 2013), we found their abundance only slightly increasing with age. Analogously, Barsoum et al. (2014) found that Araneae and Carabidae diversity showed no differences between monoculture pine and monoculture oak stands, as well as Spitzer et al. (2008), who investigated the effects of stand openness on carabids, arachnids and myriapods-isopods in lowland deciduous woodland. In a boreal forest context, Niemela et al. (1996) found that populations of Araneae, Formicidae and Carabidae showed an increasing trend only after the first 20 years. Collembola have been reported as more abundant in coppices than in other forest types (Lauga-Reyrel & Deconchat 1999); however, their abundance was not clearly delineated among coppice oak stand types in our study.

Although Sessile oak, Hungarian oak, Turkey oak, Pedunculate oak and Aleppo oak are fairly common oak species in Thrace (Yaltirik & Efe 1988, Makineci 2005), the latter two species were absent at our study sites. This could be due to the overall rarity of Aleppo oak on one side, and on the other side to the absence in the studied areas of floodplain forests, which have a high abundance of Pedunculate oak (Kavgaci et al. 2010). Forest structure, tree species, climate, elevation and parent material influence understory and density of oak species (Yarci 2000). Litter increased with understory and stand age (Makineci et al. 2011). Relationships between the arthropod community and understory in our study were inconclusive. Although the relationship between coarse woody debris and arthropod communities varies (Hanula et al. 2006, Ulyshen & Hanula 2009), it is known that both woody debris and deadwood abundance can increase arthropod diversity (Topp et al. 2006). Coarse woody debris not only increases arthropod species numbers, but also functional diversity (Jabin et al. 2004). The removal and addition of litter had no influence on arthropod diversity and taxonomic richness in lowland rainforests (Ashford et al. 2013). In general, arthropod diversity increases with vegetation height, complexity (Longcore 2003) and plant species richness (Knops et al. 1999, Symstad et al. 2000).

Cluster analysis suggested that the RTUs composition of degraded forests differed from other stand types, except at Kirklareli, but young and middle-aged forests were not clearly separated by differences in arthropod taxonomy. In cluster analysis, trap types were separated from each other, except for the sweep net trap in the "c" stand type in Catalca (CcSw). Arthropod taxonomic composition was similar between canopy (sticky traps and cloth shaking) and sub-canopy (sweepnet) locations, because of their similar ecology, whereas composition of soil-dwelling arthropods (pitfalls) differed more than canopy and sub-canopy communities. A separation between stand types was demonstrated by PCA based on 19 different parameters, with degraded forest and young forests exhibiting similar characteristics. Effects of site history on insect communities may continue for more than 20 years post-harvest (Goßner et al. 2008).

Conclusion

The results of the present study show that arthropod richness, diversity and composition in Thrace were not significantly distinguished in young and middle-aged forest stand types in coppice oak forests, although biodiversity, richness and number of specimens did slightly increase with DBH and tree height. As the coppice oak changes to mature forest, similar studies are needed to better assess the relation between arthropods and forest type and characteristics.

Several insect families could potentially be used as indicators for coppice oak conditions due to their decreasing (Formicidae, Thripidae, Lygaeidae, Dolichopodidae and Luaxanidae) or increasing (Cicadellidae and Ichneumonidae) abundance with forest age. However, in our study Araneae, which are often used as indicators, were not useful to this purpose. Arthropod taxonomic composition of degraded forests was clearly separated from the other stand types.

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