NORTH-WESTERN JOURNAL OF ZOOLOGY 21 (1): 31 - 35
Article No.: e251305

http://biozoojournals.ro/nwjz/index.html

Zerconidae mites of Spil Mountain National Park (Manisa, Türkiye): influences of altitude and habitat on the species composition

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Received: 11 January 2024 / Accepted: 28 February 2025 / Available online: June 2025 / Printed: June 2025

Abstract. The zerconid mites in the Spil Mountain National Park (Manisa, Türkiye) were studied monthly from September 2022 to August 2023, focusing on altitude and habitat preferences. After analyzing 824 samples, we identified ten zerconid mite species, with a total density of 502.195 individuals per square meter across the sampling sites. The most abundant species were *Zercon colligans* (69.7%), *Zercon izmirensis* (21.7%), and *Zercon huseyini* (7.5%). The analysis of variance was applied to assess the impact of altitude and habitat preferences on zerconid mites. A significant relation was observed between the abundance of *Z. colligans* and altitude ($p < 0.05$). This species was prevalent at elevations between 250 and 1250 meters but declined sharply beyond 1500 meters. In contrast, the population densities of other zerconid mite species continued to rise as altitude increased. Regarding habitat preferences, a statistically significant relationship ($p < 0.05$) was identified between the population densities of *Z. izmirensis* and specific habitat types. High densities of this species were found in litter and soil samples collected from beneath *Juniperus sabina*.

Keywords: Acari, Zerconidae, soil ecology, habitat preferences, species list, abundance.

Introduction

The members of the Zerconidae family are small mesostigmatic mites and they colonise different habitat types, such as soil substrates, humus, decomposed litter, leaf mould, mosses, lichens, etc., with some rare records from wood substrates, ant-hills, nests of small terrestrial mammals and birds (Mašán & Fenda 2004). Their diet includes eggs, larvae, nymphs of other mites, springtails, and nematodes (Shereef et al. 1984, Martikainen & Huhta 1990). Distributional records of zerconid mites are globally available only from the Northern Hemisphere, where more than 500 species have been identified (Kaczmarek et al. 2020). Several studies have been conducted on the taxonomy of zerconid mites in Türkiye, which resulted in identifying 136 species belonging to *Prozercon* and *Zercon* genera so far (Urhan et al. 2024).

Natural forests are considered to offer the most favorable conditions for the development of the zerconid mites. At the same time, meadows, especially agroecosystems that are completely artificial, proved to be unfavorable (Călugăr 2021). There are some studies on the habitat and altitude preferences of zerconid mites in Türkiye (Keçeci et al. 2021, Bulut et al. 2021, Bilki et al. 2022, Urhan & Karaca 2023, Urhan et al. 2024). In this study we tried to investigate the effect of elevation and habitat factors on the abundance values of zerconids found in the Spil Mountain National Park.

Materials and methods

Sampling area

The research site encompasses the Spil Mountain National Park (shortly SMNP), situated within the coastal section of the Aegean Region, positioned at latitudes 38°34′11″N and longitudes 27°25′53″E. SMNP is one of the important protected areas in the country. This protected area was declared a national park in 1994, and its acreage is nearly 7 thousand hectares.

Rising to an elevation of 1517 meters at its peak, the geological composition of SMNP is characterized by the Bornova complex, consisting of spilite, radiolarite, diabase, ophiolite, and limestone blocks (Erdoğan 1990). Different vegetation zones have emerged on the mountain depending on altitude, precipitation, temperature, and topographic conditions. In the altitudinal range up to 850 meters on the northern slopes and up to 950 meters on the southern slopes, the landscape is dominated by drought-tolerant red pine, maquis, and garig vegetation, characterized by preferences for high temperatures and ample light. Moving beyond this elevation, the Mediterranean Mountain Belt becomes evident, marked by the presence of black pines (*Pinus nigra* subsp. *pallasiana*), as altitude increases and temperatures decrease. Typically, beyond 1350 meters, the transition occurs from the sub-alpine vegetation-like layer, characterized by the presence of Iranian-Turanian elements, owing to influences such as wind and anthropogenic disturbances. This transition marks the passage into a zone with heightened anthropogenic characteristics. Red-colored Mediterranean soils are common on the Mesozoic limestones that cover large mountain areas at the bottom of karst depressions. Calcareous brown forest soils are generally seen on the Flysch formation and Neogene deposits covered with Red Pine and Black Pine forests. In the eastern parts of the mountain, rendzinas from calcimorphic intrazonal soils are encountered in clayey-calcareous Neogene deposits (Semenderoğlu 2020). This study aims to reveal the zerconid mite fauna of SMNP and investigate whether elevation and habitat factors affect abundance.

Sampling

Different materials (various plant litters and soil samples), containing zerconid mites, were taken monthly from 18 sites in SMNP (Manisa Province) from September 2022 to August 2023 by using a 15×15 cm diameter sampling cylinder at each site (Figure 1). These sites were strategically chosen across various altitudes and habitats (plant litter), from 250 meters above sea level (a.s.l.) and ascending to 1500 meters. Sampling sites were divided according to 250-meter elevation ranges. Debris from tree communities spread throughout the region such as: *Quercus coccifera*, *Q. infectoria*, *Pinus pinea, P. brutia*, *P. nigra*, *Juniperus sabina* were chosen as habitat types. Litter and soil samples collected from the field were placed in plastic storage bags, labeled, and transported to the laboratory. Samples were put in Berlese-Tullgren funnels for extracting mites for 4–5 days, then preserved in 70% ethanol, cleared in 60% lactic acid, and finally mounted on microscope

slides using Hoyer's medium. The identifications of zerconids were done using a light microscope (Olympus CX41), and the illustrations were drawn with a DP25 camera attached to an Olympus BX50 microscope. All the specimens we examined were deposited. The idiosomal setation follows Lindquist & Evans (1965), with modifications for the caudal region as in Lindquist & Moraza (1998).

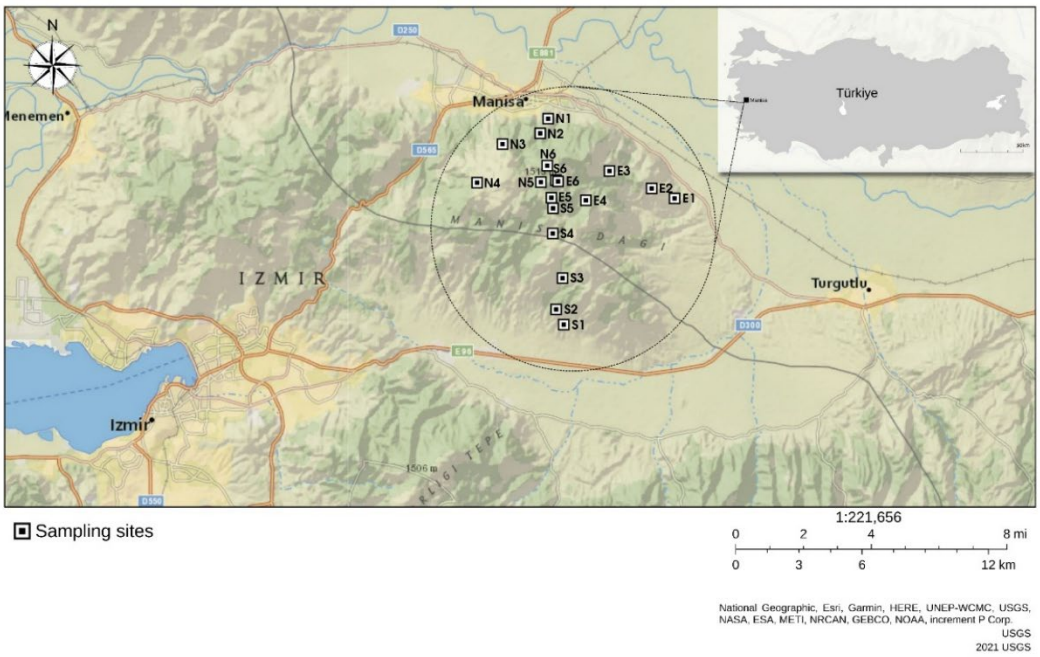

Figure 1. Sampling sites on Spil Mountain. Sampling points are named according to their location in the North (N1-N6), South (S1-S6), and East (E1-E6) directions, representing three different routes.

Statistical Analysis

The relative abundance percentage of each species was calculated for each station (Selvin & Vacca 2004). In this study, we used the TUKEY post-hoc test to analyze at which elevation values the densities of zerconid mites differed statistically, and we employed ANOVA alongside post-hoc tests to elucidate the correlation between individual mite densities and habitat-altitude factors. We assigned altitudes and habitats as fixed factors. We used the IBM SPSS Statistics 27 program. The individual densities of the zerconid mites were assigned as dependent variables, and habitats and altitudes in the soil where the samples were taken were assigned as independent variables.

Results

Species list and abundance

As a result, 502.195 individuals/m² belonging to the Zerconidae family were recorded from the study areas. The research led to the identification of three species from the genus *Prozercon* and seven species from the genus *Zercon* in the collected samples (Table 1). Population densities of species as percentages: 69.7% *Z. colligans*, 21.7% *Z. izmirensis*, 7.55% *Z. huseyini*, 0.4% *Z. burdurensis*, 0.02% *Z. kallimci*, 0.07% *Prozercon rekaae*, 0.2% *P. erdogani*, 0.05% *Z. dilekensis*, 0.08% *P. katae*, 0.02% *Z. andrei* (Table 2).

The relative abundance of the species was calculated for each altitude. In terms of relative abundance percentages, three species were found to be present across all altitudes and microhabitats: *Z. colligans*, *Z. huseyini*, and *Z. izmirensis*. *Z. colligans* was recorded as the species with the highest percentage in all stations except for 1500 meters a.s.l. At 1500 meters a.s.l *Z. izmirensis* had higher numerical values in terms of relative abundance percentage (Table 3).

Table 1. List of species belonging to the Zerconidae family identified in the study area.

Genus	Species
Zercon	*Z. andrei* Sellnick, 1958
	Z. burdurensis Urhan, 2000
	Z. colligans Berlese, 1920
	Z. dilekensis Urhan & Karaca, 2023
	Z. huseyini Urhan, 2008
	Z. izmirensis Urhan, Duran & Karaca, 2021
	Z. kallimcii Urhan, 2010
Prozercon	*P. erdogani* Urhan & Ayyıldız, 1996
	P. katae Ujvári 2004
	P. rekaae Ujvári, 2008

Table 2. Individual densities and percentages of the zerconid mite species recorded in the study

Species	Total individuals (m²)	Percentages of densities (%)
Z. colligans	350252	69.74
Z. izmirensis	109395	21.78
Z. huseyini	37928	7.55
Z. burdurensis	2156	0.42
Z. kallimcii	132	0.02
Z. andrei	132	0.02
Z. dilekensis	264	0.05
P. katae	440	0.08
P. erdogani	1100	0.21
P. rekaae	396	0.07
Total	502195	

Table 3. Relative abundance percentages of zerconid mite species detected at the stations.

Site	*Z. colligans*	*Z. izmirensis*	*Z. huseyini*	*Z. burdurensis*	*Z. kallimcii*	*P. rekaae*	*P. erdogani*	*Z. dilekensis*	*P. katae*	*Z. andrei*
E1	79.60	16.26	4.00	-	0.13	-	-	-	-	-
E2	90.50	6.51	2.26	0.42	-	0.28	-	-	-	-
E3	67.91	25.24	6.67	-	-	-	-	-	-	-
E4	66.93	26.18	6.77	-	-	0.11	-	-	-	-
E5	49.25	30.14	11.85	8.75	-	-	-	-	-	-
E6	33.82	58.08	8.08	-	-	-	-	-	-	-
S1	88.02	10.90	-	-	-	-	-	-	1.06	-
S2	85.15	11.67	2.91	-	0.24	-	-	-	-	-
S3	83.80	12.42	3.30	-	-	-	-	-	-	0.47
S4	74.44	11.66	13.20	-	-	-	0.51	0.17	-	-
S5	85.04	7.00	6.33	1.61	-	-	-	-	-	-
S6	28.82	52.50	17.79	-	0.14	-	-	-	0.73	-
N1	89.54	1.71	7.98	-	-	-	0.57	-	-	-
N2	93.65	1.65	4.69	-	-	-	-	-	-	-
N3	77.82	4.08	17.89	-	-	-	0.19	-	-	-
N4	74.35	21.54	3.94	-	-	-	0.15	-	-	-
N5	60.95	28.92	7.40	-	-	0.41	1.77	0.52	-	-
N6	33.43	54.35	11.75	-	-	0.30	-	-	0.15	-

Individual densities of *Z. colligans*, *Z. izmirensis,* and *Z. huseyini* were used in the variance analysis. Other species were not included in the statistical analysis since they were not regularly detected monthly and at every station. According to the population densities, the highest and lowest densities of these three zerconid species in different habitats and altitudes are mentioned. 12-month total densities of these mites according to their altitudes; *Z. colligans* a total of 73391 individuals (shortly ind.) per square meter (shortly psm.) were observed at 500 m a.s.l maximum, 27280 (ind psm) at 1500 m a.s.l minimum; *Z. izmirensis*; 46860 (ind. psm.) at 1500 m a.s.l maximum, 4664 (ind. psm.) at 500 m a.s.l minimum; *Z. huseyini* 10868 (ind. psm.) at 1500 m a.s.l maximum, 2728 (ind. psm.) at 500 m a.s.l. minimum.

12-month total densities of these mites according to their habitats; *Z. colligans* highest under *P. nigra* (76382 (ind. psm.), lowest under *P. brutia* 26268 (ind. psm.), *Z. izmirensis* highest under *J. sabina* 59059 (ind. psm.), lowest under *Q. infectoria* 836 (ind. psm.), *Z. huseyini* highest under *J. sabina* 13992 (ind. psm.), lowest under *Q. infectoria* 836 (ind. psm.).

Altitude preferences

The altitudinal distribution results of the species were marked in Table 4. When the total population densities for each of the three zerconid mite species were analysed concerning altitude values, the differences were statistically significant only for *Z. colligans* (F: 2.509, $p<0.05$).

The differences between *Z. izmirensis* and *Z. huseyini* were not statistically significant ($p>0.05$). For *Z. colligans*, we applied the post hoc test (Table 5). When the post hoc multiple comparison was analysed, the difference between the population densities recorded at 250-1500 m a.s.l. and 500-1500 m a.s.l. made the altitude statistically significant for *Z. colligans*.

Table 4. Altitude preferences of zerconid mites in the SMNP.

Altitudinal ranges /species	*Z. colligans*	*Z. izmirensis*	*Z. huseyini*	*Z. burdurensis*	*Z. kallimcii*	*Z. dilekensis*	*Z. andrei*	*P. katae*	*P. rekaae*	*P. erdogani*
250	✓	✓	✓							✓
500	✓	✓	✓					✓	✓	✓
750	✓	✓	✓				✓		✓	✓
1000	✓	✓	✓	✓		✓			✓	✓
1250	✓	✓	✓	✓		✓				✓
1500	✓	✓	✓		✓			✓		

Habitat preferences

In the research area, samplings of zerconid mites were carried out in 18 different localities and the habitats were noted under the following six species: *J. sabina*, *P. brutia*, *P. nigra*, *P. pinea*, *Q. coccifera*, *Q. infectoria*. The habitat preferences of the species were marked in Table 6. When the total population densities for the three zerconid mite species were analysed relative to habitat, the differences were statistically significant only for *Z. izmirensis* (F: 1.996; $p<0.05$, respectively). The differences between *Z. colligans* and *Z. huseyini* were not statistically significant ($p>0.05$). We applied the post hoc test (Tukey) for *Z. izmirensis*. *Z. izmirensis* total individual densities were different between the habitats represented by *P. nigra*-*Q. coccifera*, *Q. coccifera*-*J. sabina*, *J. sabina*-*Q. infectoria* (Table 7).

Table 5. One-way ANOVA and post hoc results (Altitude dependent of *Z. colligans*, *Z. izmirensis*, and *Z. huseyini*).

	Sum Sq	Mean Sq	F Value	*p*-value
Z. colligans	308378315.493	1275624.262	2.509	.029*
Z. izmirensis	130207970.558	624207.697	1.027	.403
Z. huseyini	10666769.981	46834.287	.916	.472
Post-Hoc	*Z. colligans*			
Altitude (a.s.l.)	Std. Error	Lower	Upper	*p*-value
250-1500	98.154*	9.77	576.59	.038*
500-1500	365.261*	83.74	646.78	.003*

*:Significance level $p < 0.05$.

Table 6. Habitat preferences of zerconid mites in the SMNP.

Habitats/species	***Z. colligans***	***Z. izmirensis***	***Z. huseyini***	***Z. burdurensis***	***Z. kallimcii***	***Z. dilekensis***	***Z. andrei***	***P. katae***	***P. rekaae***	***P. erdogani***
Q. coccifera	✓	✓	✓						✓	✓
Q. infectoria	✓	✓	✓							
P. brutia	✓	✓	✓						✓	✓
P. nigra	✓	✓	✓	✓	✓	✓	✓	✓		✓
P. pinea	✓	✓	✓					✓		✓
J. sabina	✓	✓	✓	✓		✓		✓		✓

Table 7. One-way ANOVA and post hoc results (Habitat dependent of *Z. colligans*, *Z. izmirensis*, and *Z. huseyini*).

	Sum Sq	Mean Sq	F Value	Pr (>F)
Z. colligans	7462748.569	932843.571	1.832	.068
Z. izmirensis	9367984.018	1170998.002	1.996	.048
Z. huseyini	322958.546	40369.818	.784	.617
Post-Hoc	*Z. izmirensis*			
Depth	Std. Error	Lower	Upper	*p*-value
P. nigra-Q. coccifera	78.278	16.90	524.14	0.028*
J. sabina-Q. coccifera	96.604	223.41	835.94	<0.001
J. sabina-Q. infectoria	103.874	150.63	814.06	<0.001

*:Significance level $p < 0.05$.

Discussion

Most studies on zerconid mites in Türkiye and the world are focused on systematic research. Therefore, ecological studies have received less attention (Mašán & Fenda 2004, Kahveci et al. 2006, Urhan et al. 2008), although they are significant for understanding the ecology of this mite group.

When the total individual abundances of zerconid mites were analysed depending on the altitude values, it was observed that only the abundances of *Z. colligans* species differed statistically depending on the altitude. At 500 m a.s.l., this species was recorded at the highest densities in litter and soil samples. At 1500 meters a.s.l., the lowest population densities were observed where *Z. izmirensis* and *Z. huseyini* total abundances were the highest.

Previously, individuals of *Z. izmirensis* were identified from an altitude of 884 meters a.s.l. in İzmir province, Türkiye (Urhan et al. 2020). *Z. huseyini* were identified from an altitude

of 1100 meters a.s.l. in Denizli province, Türkiye (Urhan 2010). However, statistically, no relation was found between the height factor and the total number of individuals for *Z. izmirensis* and *Z. huseyini* species. After 500 metres a.s.l., we observed that the total density of individuals increased as the altitude increased.

The other seven zerconid species were detected in small amounts. We could not observe these mites monthly, so it would have been incorrect to comment on their relationship to altitude. At altitudes above 500 metres a.s.l., the densities of *Z. huseyini* and *Z. izmirensis* species increased numerically. The increased abundance and diversity of other zerconid mites can explain this. For example, three species were identified from 250 m a.s.l., and between 750-1250 metres a.s.l. seven zerconid species were identified. Generally, with increasing altitude, the abundance and diversity of other zerconid species increased, leading to a decrease in the numerical values of *Z. colligans.* From an ecological point of view, since these species were detected from the same habitats, food competition between species and increased diversity may explain these numerical changes.

Z. burdurensis, *Z. kallimcii*, *Z. dilekensis*, *Z. andrei*, *P. katae*, *P. rekaae,* and *P. erdogani* were not included in the ANOVA test because their densities were too low. However, there is no discrepancy with the height values of these species in the holotype descriptions given in the past. According to the altitudinal ranges of this species, it is understood that *Z. burdurensis* occurs 1000-1500 m a.s.l., *Z. kallimcii* occurs only 1500 m a.s.l., *Z. dilekensis* 1000-1250 m a.s.l., *Z. andrei* only 750 m a.s.l., *P. rekaae* 500-1000 m a.s.l., *P. erdogani* 250-1250 m a.s.l. *P. katae* was detected at 500 m a.s.l. and 1500 m a.s.l. The height at which *P. katae* species was found in the holotype description has not been given in the past (Ujvári & Călugăr 2010). We could not comment on altitude preference as these species were not adequately characterised in abundance.

Z. colligans is widespread in Türkiye and may be found in all directions (Karaca 2020). This species has the highest relative abundance value at all altitudes except 1500 metres. After 1250 m a.s.l., *Z. colligans* total abundances showed a significant decrease. Z. *izmirensis* was the most abundant species at 1500 m a.s.l. Based on the results of the present study, we can conclude that altitude clearly affects the individual densities of *Z. colligans*. This species, dense between 250 and 1250 m a.s.l., showed a drastic decline above 1250 m a.s.l. Future studies in different regions will support these elevation preferences of *Z. colligans* in SMNP. *Z. izmirensis* was recorded at high densities under *J. sabina* and *P. nigra*, low densities under *Q. coccifera* and *Q. infectoria* habitats. The holotype was identified under *Q. coccifera*, paratypes under *P. nigra* and *Pyrus elaeagrifolia* (Urhan et al. 2020). The high densities of this species in *J. sabina* samples contributed to the literature information. In this study, in terms of habitat preference, it was found that the species was less abundant in *Q. infectoria* habitats in our research area. *P. nigra* and *J. sabina* provided favourable conditions for zerconids` development. Future studies should support the favourable environmental conditions provided by these habitats.

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