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# Altitudinal variations in the structure and composition of oribatid mite community in the Arjan Plain Biosphere Reserve, Fars Province, Iran

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**ABSTRACT.** Data was collected from 45 monthly samples at three vegetation layers spanning from 1950 to 2500 meters above sea level in the Arjan Plain Biosphere Reserve, Fars Province, Iran. A total of 12,648 individuals were collected, leading to the identification of 89 species of oribatid mites from 39 families and 53 genera The data for the Shannon diversity index was analyzed using the permutation one-way analysis of variance (PERMANOVA) to understand the distribution of mites across the elevation gradients. Significant variations were observed in the distribution of oribatid mites at different elevational strata. Layer 2 exhibited the highest species richness and total abundance of oribatid mites, with 67 species and 6162 individuals, followed by layer 3 with 62 species and 4359 individuals, and layer 1 harbouring 59 species and 2140 individuals. Dominant species included *Jacotella frondeus* (Kulijev) and *Oribatula pallida* Banks in layer 1, *Pilogalumna tenuiclava* (Berlese), *Aleurodamaeus* sp.3, and *J. frondeus* in Layer 2, and *Aleurodamaeus* sp.3 and *J. frondeus* in layer 3. The Shannon index also revealed that species diversity of oribatid mites significantly increased with elevation increase. Furthermore, the analysis indicated a notable seasonal effect on oribatid mite biodiversity, demonstrating the lowest species richness and abundance observed in July and September.

**Keywords:** Altitudinal gradient, Beetle mites, species diversity, soil ecology

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## INTRODUCTION

Due to their importance as topsoil decomposers, the diversity and abundance of oribatid mites make them valuable bioindicators of soil health in specific habitats (Abliz et al., 2014). The Arjan-Parishan Biosphere Reserve recognized as an important biosphere reserve (ABR), was designated by UNESCO in 1976. It is located 60 km southwest of Shiraz in Fars Province, southern Iran. The ABR boasts a unique landscape that includes Parishan Lake, Arjan Wetland, springs, and valleys in the Zagros Mountain ranges. Encompassing approximately 91,860 hectares of forests, rangelands, and agricultural lands, the region is a haven for diverse flora and fauna. While some studies have focused on the biodiversity of plants and animals in the ABR (Dolatkhahi et al., 2012, 2014; Sadeghian et al., 2019), the diversity of the oribatid mite community remains largely unexplored.

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The variation in elevation of mountains has a significant impact on both abiotic and biotic factors, ultimately influencing the distribution of species and their richness across different geographical scales (Leahy et al., 2020, 2021; McCain & Grytnes, 2010; Scheffers et al., 2013; Veijalainen et al., 2014). Numerous studies have highlighted the importance of altitudinal shifts in species distribution patterns among surface-dwelling animals (Chesshire et al., 2021; Nogueira et al., 2021; Peters et al., 2016).

However, there is a lack of information regarding this phenomenon when it comes to soil-dwelling microarthropods like oribatida. Oribatida, a group of mites, consists of a total of 11,628 described species and subspecies worldwide. In Iran, the latest list of oribatid mites includes 380 species from 191 genera (Akrami, 2015). This research aims to conduct a comprehensive survey of the oribatid mite community in the Arjan Biosphere Reserve. The goal was to generate reliable insights into oribatid mite abundance and distribution patterns across varying elevation gradients. By shedding light on the ecology of oribatid mites in this region.

## MATERIAL AND METHODS

***Study area and sampling procedure.*** The research was conducted in the Arjan-Parishan Biosphere Reserve (ABR) located in Fars Province, southwest Iran in 2015. Three layers of soil were selected with elevations ranging from 1950 m to 2500 m above sea level. The elevation ranges of each layer are as follows: layer 1 (1950–2130m), layer 2 (2150–2320m), and layer 3 (2340–2500m). Sampling was conducted monthly from May to October 2015. Within each elevation layer, three randomly selected rectangular plots measuring 10 × 10 meters (100 square meters) were designated for sampling. Each plot consisted of five samples, totalling 45 samples per month. The sampling process involved the use of a metal cylinder measuring 9 × 10 square centimeters with a volume of 196.25 cubic centimeters.

***Mite extraction and morphological identification.*** The soil samples were sent to the Acarological laboratory at Shiraz University for mite extraction using the Berlese-Tullgren apparatus. Oribatid mites were carefully extracted, cleared, and then mounted in Hoyer's medium on glass microscope slides. These slides were then placed in an oven set at 45°C for a period of 10 days. Adult oribatid specimens were meticulously examined using a light microscope, specifically the Zeiss® Standard 20 model. Species-level identification was conducted by the second author, an esteemed Iranian specialist in oribatid mites. The mites were classified as morphological species based on this expert analysis. All specimens were meticulously preserved and deposited in the Acarological Collection of the Department of Plant Protection at the School of Agriculture, Shiraz University, located in Shiraz, Iran.

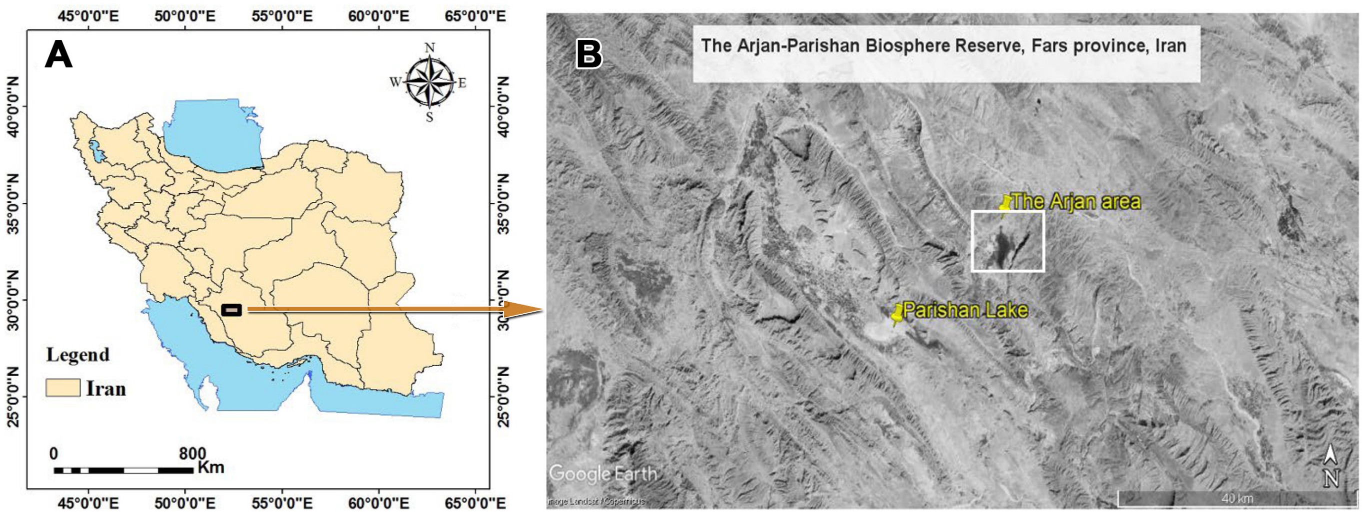


**Figure 1.** The Arjan Biosphere Reserve (ABR), Fars Province, Iran. **A.** Location of the study site in Iran; **B.** The specific sampling region is highlighted by the white rectangle.

***Community structure.*** The relative abundance (D) of each oribatid species was calculated by dividing the number of individuals of each species by the total number of individuals across all species. The dominance class of each species was determined using the procedure outlined by Engelmann (1978). Species were categorized as follows: Eudominant (Eu): species with over 32–100% of all collected individuals; Dominant (Do): 32–10%; Subdominant (Sd): 10–3.2%; Recedent (Rc): 3.2–1%; Subrecedent (Sr): 1–0.32%; Sporadic (Sp): less than 0.32% of all individuals. This classification system provides a clear and standardized method for understanding the distribution and prevalence of oribatid species within a given ecosystem.

***Data analyses.*** In order to assess the impact of elevation and month on the diversity of the oribatid mite community, a permutation analysis of variance (PERMANOVA) was conducted using commands outlined in SAS software (Anderson, 2001). The Shannon index was then computed for each layer and month utilizing SDR4 software (Seaby & Henderson, 2006). The permutation ANOVA was used for the analysis of the Shannon index and the means were compared using the least significant differences (LSD) test at a 0.05 probability level.

## RESULTS

***Observed species richness and community structure.*** In 2015, a total of 12,648 oribatid mites were collected from the Arjan Biosphere Reserve (ABR), consisting of 89 morphospecies from 39 families and 58 genera (Table 1). Some of these species were newly discovered in Iran, with all species being recorded for the first time in ABR (Iranpoor & Akrami, 2016). Notably, 26 of these species are potentially new and require further taxonomic examination. The most prevalent species found was *Jacotella frondeus*, representing 20.98%, 11.30%, and 16.06% of individuals in Layers 1–3, respectively (Table 1). *Oribatula pallida* was dominant in Layer 1, while *Aleurodamaeus* sp.3 and *Pilogalumna tenuiclava* were dominant in Layer 2, and *Aleurodamaeus* sp.3 in Layer 3. Interestingly, *Ghilarovus hispanicus* was a subdominant species in Layers 1 and 2 but was recedent in Layer 3. Additionally, *Aleurodamaeus* sp.1, *Sphaerochthonius splendidus*, *Licnodamaeus* sp.2, and *Peloribates* sp. were subdominant in Layers 2 and 3 but recedent in Layer 1. Conversely, *Oribatula frisiae*, *Oribatula skrjabini*, *Scheloribates* sp.2, and *Galumna iranensis* were subdominant in Layer 1 but subrecedent, sporadic, or missing in Layers 2 and 3. *Haplozetes fusifer* and *Belba dubinini*, absent in Layer 1, were classified as subdominant species in Layers 2 and 3 (Table 1).

**Table 1.** List of oribatid species ranked in order of abundance in the three altitudinal layers of the Arjan Biosphere Reserve, Iran in 2015.

| # | Species | Layer 1 | | Layer 2 | | Layer 3 | |
|---|---|---|---|---|---|---|---|
| | | RA (%) | Do | RA (%) | Do | RA (%) | Do* |
| 1 | *Jacotella frondeus* (Kulijev, 1979) | 20.98 | Do | 11.30 | Do | 16.06 | Do |
| 2 | *Oribatula pallida* Banks, 1906 | 10.23 | Do | 5.66 | Sd | 5.71 | Sd |
| 3 | *Aleurodamaeus* sp.3 | 8.27 | Sd | 10.18 | Do | 10.71 | Do |
| 4 | *Pilogalumna tenuiclava* (Berlese, 1908) | 0.14 | Sp | 14.82 | Do | 9.80 | Sd |
| 5 | *Ghilarovus hispanicus* Subías & Pérez-Íñigo, 1977 | 4.11 | Sd | 3.83 | Sd | 2.50 | Rc |
| 6 | *Aleurodamaeus* sp.1 | 2.62 | Rc | 4.35 | Sd | 5.85 | Sd |
| 7 | *Sphaerochthonius splendidus* (Berlese, 1904) | 1.59 | Rc | 8.21 | Sd | 5.44 | Sd |
| 8 | *Licnodamaeus* sp.2 | 2.15 | Rc | 8.20 | Sd | 7.16 | Sd |
| 9 | *Peloribates* sp. | 1.68 | Rc | 6.49 | Sd | 8.86 | Sd |
| 10 | *Oribatula frisiae* (Oudemans, 1900) | 7.38 | Sd | 0.15 | Sp | 0.14 | Sp |
| 11 | *Oribatula skrjabini* (Bulanova-Zachvatkina, 1967) | 6.40 | Sd | 0 | Ms | 0.11 | Sp |
| 12 | *Scheloribates* sp.2 | 3.74 | Sd | 0.02 | Sp | 0.02 | Sp |
| 13 | *Haplozetes fusifer* (Berlese, 1908) | 0 | Ms | 5.71 | Sd | 3.49 | Sd |
| 14 | *Galumna iranensis* Mahunka & Akrami, 2001 | 4.39 | Sd | 0.71 | Sr | 0.07 | Sp |
| 15 | *Belba dubinini* (Bulanova-Zachvatkina, 1962) | 0 | Ms | 3.56 | Sd | 4.27 | Sd |
| 16 | *Cosmochthonius reticulatus* Grandjean, 1947 | 3.08 | Rc | 2.63 | Rc | 1.33 | Rc |
| 17 | *Camisia horrida* (Hermann, 1804) | 1.03 | Rc | 1.82 | Rc | 1.86 | Rc |
| 18 | *Tectocepheus velatus* (Michael, 1880) | 2.29 | Rc | 0.62 | Sr | 3.14 | Rc |
| 19 | *Licnodamaeus inaequalis* (Balogh & Mahunka, 1965) | 0.05 | Sp | 1.48 | Rc | 1.38 | Rc |
| 20 | *Cosmochthonius zanini* Penttinen & Gordeeva, 2003 | 0.19 | Sp | 0.5 | Rc | 0.87 | Rc |
| 21 | *Phthiracarus furvus* Niedbała, 1983 | 0 | Ms | 1.53 | Rc | 1.47 | Rc |
| 22 | *Galumna karajica* Mahunka & Akrami, 2001 | 2.48 | Rc | 0.84 | Sr | 0.62 | Sr |
| 23 | *Ramusella damavandica* Akrami & Subías, 2008 | 1.68 | Rc | 0.84 | Sr | 0.50 | Sr |
| 24 | *Epilohmannia cylindrica cylindrica* (Berlese, 1904) | 1.21 | Rc | 0.42 | Sr | 0.46 | Sr |

| # | Species | Layer 1 | | Layer 2 | | Layer 3 | |
|---|---|---|---|---|---|---|---|
| | | RA (%) | Do | RA (%) | Do | RA (%) | Do* |
| 25 | *Licnodamaeus* sp.5 | 0.28 | Sp | 1.07 | Rc | 0.41 | Sr |
| 26 | *Neoribates granulatus* Akrami & Behmanesh, 2012 | 0.23 | Sp | 0.91 | Sr | 1.01 | Rc |
| 27 | *Haplochthonius sanctaeluciae* Bernini, 1973 | 1.26 | Rc | 0.13 | Sp | 0.05 | Sp |
| 28 | *Acrotritia pirovaci* Niedbała, 2006 | 1.26 | Rc | 0.02 | Sp | 0.02 | Sp |
| 29 | *Zetomotrichus lacrimans* Grandjean, 1934 | 1.17 | Rc | 0.05 | Sp | 0.30 | Sp |
| 30 | *Aphelacarus acarinus acarinus* (Berlese, 1910) | 2.33 | Rc | 0.05 | Ms | 0 | Ms |
| 31 | *Christovizetes iranensis* Akrami & Behmanesh, 2011 | 0.33 | Sr | 0.42 | Sr | 0.07 | Sp |
| 32 | *Cosmochthonius ponticus* Gordeeva, 1980 | 0.28 | Sp | 0.62 | Sr | 0.85 | Sr |
| 33 | *Aleurodamaeus* sp.2 | 0.09 | Sp | 0.28 | Sp | 0.53 | Sr |
| 34 | *Micropia minus minus* (Paoli, 1908) | 0.05 | Sp | 0.13 | Sp | 0.44 | Sr |
| 35 | *Rhinoppia obsoleta* (Paoli, 1908) | 0.05 | Sp | 0.02 | Sp | 0.6 | Sr |
| 36 | *Ramusella persica* Akrami, Behmanesh & Subías, 2015 | 0.93 | Sr | 0.02 | Sp | 0 | Ms |
| 37 | *Graptoppia sundensis* (Hammer, 1979) | 0.42 | Sr | 0.03 | Sp | 0 | Ms |
| 38 | *Hemileius* sp.1 | 0.47 | Sr | 0.02 | Sp | 0 | Ms |
| 39 | *Zetomotrichus persicus* Akrami & Behmanesh, 2013 | 0.84 | Sr | 0 | Ms | 0.02 | Sp |
| 40 | *Nothrus anauniensis* Canestrini & Fanzago, 1877 | 0.42 | Sr | 0 | Ms | 0.09 | Sp |
| 41 | *Oribatula connexa connexa* Berlese, 1904 | 0.79 | Sr | 0 | Ms | 0 | Ms |
| 42 | *Sellnickochthonius gracilis* (Chinone, 1974) | 0.75 | Sr | 0 | Ms | 0 | Ms |
| 43 | *Licnobelba latiflabellata* (Paoli, 1908) | 0 | Ms | 0.63 | Sr | 0.09 | Sp |
| 44 | *Phyllozetes emmae* (Berlese, 1910) | 0 | Ms | 0.39 | Sr | 0.25 | Sp |
| 45 | *Suctobelba subtrigona* (Oudemans, 1900) | 0 | Ms | 0.02 | Sp | 0.39 | Sr |
| 46 | *Papillacarus aciculatus* (Berlese, 1904) | 0 | Ms | 0.41 | Sr | 0 | Ms |
| 47 | *Hermanniella grandis* Sitnikova, 1973 | 0 | Ms | 0 | Ms | 0.76 | Sr |
| 48 | *Oppiella* sp. | 0 | Ms | 0 | Ms | 0.62 | Sr |
| 49 | *Protoplophora iranica* Akrami & Behmanesh, 2012 | 0.19 | Sp | 0.06 | Sp | 0.06 | Sp |
| 50 | *Licnodamaeus* sp.4 | 0.14 | Sp | 0.05 | Sp | 0.02 | Sp |
| 51 | *Lasiobelba* sp. | 0.14 | Sp | 0.15 | Sp | 0.11 | Sp |
| 52 | *Austrocarabodes foliaceisetus georgiensis* Murvanidze & Weigmann, 2007 | 0.05 | Sp | 0.13 | Sp | 0.05 | Sp |
| 53 | *Berlesezetes brazilozetoides* Balogh & Mahunka, 1981 | 0.05 | Sp | 0.05 | Sp | 0.05 | Sp |
| 54 | *Scheloribates* sp.1 | 0.19 | Sp | 0.05 | Sp | 0 | Ms |
| 55 | *Allogalumna* cf. *pellucida* Wallwork, 1965 | 0.14 | Sp | 0.03 | Sp | 0 | Ms |
| 56 | *Licnodamaeus* sp.3 | 0.05 | Sp | 0.03 | Sp | 0 | Ms |
| 57 | *Licnodamaeus* sp.1 | 0.14 | Sp | 0 | Ms | 0.16 | Sp |
| 58 | *Camisia borealis* (Thorell, 1871) | 0.05 | Sp | 0 | Ms | 0.32 | Sp |
| 59 | *Xenillus setosus* Grobler, Ozman & Cobanoglu, 2003 | 0.05 | Sp | 0 | Ms | 0.02 | Sp |
| 60 | *Austrophthiracarus pavidus* (Berlese, 1913) | 0 | Ms | 0.29 | Sp | 0.09 | Sp |
| 61 | *Gilarovella demetrii* Lange, 1974 | 0 | Ms | 0.18 | Sp | 0.02 | Sp |
| 62 | *Scheloribates* sp.3 | 0 | Ms | 0.11 | Sp | 0.14 | Sp |
| 63 | *Atropacarus echinodiscus* (Mahunka, 1982) | 0 | Ms | 0.05 | Sp | 0.05 | Sp |
| 64 | *Phyllozetes* sp. | 0 | Ms | 0.02 | Sp | 0.09 | Sp |
| 65 | *Multioppia wilsoni laniseta* Moritz, 1966 | 0 | Ms | 0.05 | Sp | 0.02 | Sp |
| 66 | *Eupelops* cf. *eximius* Sitnikova, 1967 | 0 | Ms | 0.02 | Sp | 0.02 | Sp |
| 67 | *Neoppia* sp. | 0.28 | Sp | 0 | Ms | 0 | Ms |
| 68 | *Microppia minus longisetosa* Subías & Rodríguez, 1988 | 0.23 | Sp | 0 | Ms | 0 | Ms |
| 69 | *Phyllozetes latifolius* Gordeeva, 1980 | 0.23 | Sp | 0 | Ms | 0 | Ms |
| 70 | *Cosmochthonius* sp. | 0.09 | Sp | 0 | Ms | 0 | Ms |
| 71 | *Ramusella* sp. | 0.09 | Sp | 0 | Ms | 0 | Ms |
| 72 | Licneremaeidae | 0.09 | Sp | 0 | Ms | 0 | Ms |
| 73 | *Fosseremus sculpturatus* Mahunka, 1982 | 0.05 | Sp | 0 | Ms | 0 | Ms |
| 74 | *Oribatula* sp. | 0.05 | Sp | 0 | Ms | 0 | Ms |
| 75 | *Baloghiella foveolata* Akrami & Ebrahimi, 2013 | 0.05 | Sp | 0 | Ms | 0 | Ms |
| 76 | *Zetorchestes* sp. | 0 | Ms | 0.13 | Sp | 0 | Ms |
| 77 | *Atropacarus striculus* (Koch, 1835) | 0 | Ms | 0.06 | Sp | 0 | Ms |
| 78 | *Malaconothrus processus* Hammen, 1952 | 0 | Ms | 0.06 | Sp | 0 | Ms |
| 79 | *Ramusella puertomonttensis* Hammer, 1962 | 0 | Ms | 0.05 | Sp | 0 | Sp |
| 80 | *Pilobatella* sp. | 0 | Ms | 0.03 | Sp | 0 | Ms |
| 81 | *Protoribates obtusus* (Mihelčič, 1956) | 0 | Ms | 0.03 | Sp | 0 | Ms |
| 82 | *Phyllоztes tauricus* Gordeeva, 1978 | 0 | Ms | 0.03 | Sp | 0 | Ms |
| 83 | *Suctobelba naranensis* Hammer, 1977 | 0 | Ms | 0.02 | Sp | 0 | Ms |
| 84 | *Haplochthonius simplex* (Willmann, 1930) | 0 | Ms | 0.02 | Sp | 0 | Ms |
| 85 | *Epilohmannia styriaca* Schuster, 1960 | 0 | Ms | 0.02 | Sp | 0 | Ms |
| 86 | Neoliodidae | 0 | Ms | 0 | Ms | 0.28 | Sp |
| 87 | *Ramusella mihelcici* (Pérez-Íñigo, 1965) | 0 | Ms | 0 | Ms | 0.02 | Sp |
| 88 | *Suctobelba* sp. | 0 | Ms | 0 | Ms | 0.02 | Sp |
| 89 | *Bipassalozetes intermedius* (Mihelčič, 1954) | 0 | Ms | 0 | Ms | 0.02 | Sp |

**RA:** Relative Abundance; **Do:** Dominance; **Sd:** subdominant; **Rc:** recedent; **Sr:** subrecedent; **Sp:** sporadic; **Ms:** Missing.

The study revealed that Layer 2 had the highest observed species richness of oribatid mites, with a total of 66 species. This was followed by Layer 3 with 60 species and Layer 1 with 59 species, as shown in Table 2. The same pattern was observed in the total number of individuals collected. The species richness of oribatid mites varied from 0 to 19 species per soil sample, with an average of 6.45±4.13 species. Each layer contained 11, 10, and 6 unique species in layers 1–3, respectively.

***Temporal (seasonal) and altitudinal variation.*** Variations in the oribatid mite community at ABR were clearly evident in terms of richness, abundance, and the Shannon-Wiener index (*H*). The peak species richness of 74 was observed in May 2015 across all three layers that were investigated (Table 3). Throughout the season, the total abundance of oribatid mites in ABR fluctuated, with the highest number recorded in October (2520 individuals), followed by September, May, July, June, and August. However, abundance varied within each layer. In the first layer, there was a gradual increase in oribatid mite abundance followed by a decline in September. The second layer reached its peak abundance in June and July, with lower numbers in other months. September, October, and May were the months of peak abundance for oribatid mites in the third layer. The highest Shannon-Wiener index (H) value was observed in May 2015 for ABR, the first, and second layers. Interestingly, June had the highest H index for the third layer, followed by May.

**Table 2.** Community of oribatid mites in the three altitudinal layers of the Arjan Biosphere Reserve (ABR), Iran, in 2015.

| Variables | Layer 1 | Layer 2 | Layer 3 | ABR |
|---|---|---|---|---|
| Species richness | 59 | 66 | 60 | 89 |
| Total Abundance | 2127 | 6162 | 4359 | 12648 |
| Number of unique species | 11 | 10 | 6 | - |

**Table 3.** Seasonal variation of oribatid mite community in ABR, Iran, during 2015.

| Month | Variable | Layer 1 | Layer 2 | Layer 3 | ABR |
|---|---|---|---|---|---|
| | Richness | 32 | 42 | 47 | 74 |
| **May** | Abundancy | 280 | 861 | 1009 | 2150 |
| | H' | 2.29 $^{a}$±0.16 | 2.50 $^{a}$±0.18 | 2.58 $^{a}$±0.43 | 2.46$^{a}$±0.16 |
| | Richness | 15 | 36 | 25 | 43 |
| **June** | Abundancy | 276 | 1292 | 412 | 1980 |
| | H' | 2.00$^{a}$±0.21 | 2.40 $^{a}$±0.12 | 2.86 $^{b}$±0.32 | 2.09$^{b}$±0.21 |
| | Richness | 16 | 30 | 24 | 44 |
| **July** | Abundancy | 340 | 1264 | 532 | 2136 |
| | H' | 1.23 $^{b}$±0.27 | 2.23 $^{ab}$±0.02 | 2.15 $^{ab}$±0.23 | 1.87$^{b}$±0.15 |
| | Richness | 25 | 25 | 24 | 41 |
| **August** | Abundancy | 467 | 832 | 337 | 1636 |
| | H' | 1.77 $^{ab}$± 0.57 | 1.90 $^{bc}$±0.23 | 2.06 $^{b}$±0.07 | 1.91$^{b}$±0.09 |
| | Richness | 15 | 27 | 23 | 36 |
| **September** | Abundancy | 164 | 1006 | 1056 | 2226 |
| | H' | 1.36 $^{b}$±0.22 | 2.21 $^{ab}$ ±0.22 | 1.99 $^{b}$ ±0.26 | 1.86$^{b}$±0.13 |
| | Richness | 21 | 29 | 26 | 43 |
| **October** | Abundancy | 600 | 907 | 1013 | 2520 |
| | H' | 1.72 $^{ab}$±0.42 | 1.67 $^{c}$±0.43 | 2.16 $^{ab}$±0.22 | 1.86$^{b}$±0.07 |

*± numbers indicate standard deviation (SD) values, means with different letters are significantly different at 0.05 probability level.

The Permutation ANOVA revealed a significant difference in the occurrences of oribatid mite communities based on both month and altitude. In particular, July and September stood out as having a notable impact on the communities. The PERMANOVA analysis further highlighted a distinct separation between oribatid mite communities in layers 2 and 3 compared to Layer 1. Additionally, the Shannon-Wiener diversity index (H) showed higher values in layers 2 ($H$=2.16±0.16) and 3 ($H$=2.14±0.08) than in Layer 1 ($H$=1.73±0.22). This suggests a greater diversity and richness of oribatid mite communities in layers 2 and 3.

## DISCUSSION

This study presents groundbreaking biodiversity data on the oribatid mite community within the Arjan Biosphere Reserve in Iran. The research revealed a remarkable local species richness and abundance of oribatid mites, with 89 species and 12,661 individuals identified that had not been previously documented in Iran. Among the species documented, *Jacotella frondeus* emerged as the dominant species across all three layers, followed by *Aleurodamaeus* sp.3 (in layers 2 and 3), *Oribatula pallida* (in layer 1), and *Pilogalumna tenuiclava* (in layer 2). *Jacotella frondeus* exhibits a wide distribution across various regions in Iran, including East Azerbaijan, Fars, Kermanshah, Guilan, Hamadan, Kurdistan, North Khorasan, Markazi, Mazandaran, Razavi Khorasan, Sistan & Baluchestan, West Azerbaijan, Yazd, Kerman, and Zanjan Provinces. The mite, *Oribatula pallida* is frequently found in the soil of diverse vegetation types, including cypress trees, true pines, plane trees, black poplar trees, maple trees, oak trees, mount atlas pistachio trees, mountain almond trees, locoweed plants, grapevines, azarole hawthorn bushes, berberry bushes, almond trees, oleaster trees, fig trees, apple trees, grasses (such as wheat and grass), legumes (like alfalfa, clover, camel's-thorn, and pagoda), and some weeds like Bermuda grass. This species has been observed in various Provinces of Iran, including East Azerbaijan, Fars, Guilan, Mazandaran, West Azerbaijan, and Zanjan. Similarly, the mite *Pilogalumna tenuiclava* has been documented in Provinces such as Yazd, East Azerbaijan, Fars, Zanjan, Semnan, Markazi, Sistan & Baluchestan, and Kerman.

Research conducted by Akrami, Behmanesh, Rajabi, Ebrahimi, Iranpoor, Salehi Sarbizhan, Shahedi, Arbab, and Ordouni has shown that the community structure of oribatid mites in the ABR consists of 6 to 11 unique species, accounting for 7–12% of the total species, in Layers 3 to 1, respectively. Furthermore, 36 species, representing 40.5% of the total, are common across the layers studied (refer to Tables 1 and 2). A study in the central Alps, Austria, by Fischer and Schatz (2013), revealed a distinct community structure of oribatid mites along altitudinal gradients. The researchers sampled four different vegetation types across an elevation range from 2050 m to 2900 m above sea level and identified a total of 86 species. Each elevation gradient exhibited its unique community, with only four species found in all four layers. The diversity pattern of the oribatid mite community in the Arjan Biosphere Reserve exhibited an upward trend with increasing elevation. Layer 2 ($H$=2.16±0.16) was identified as having the highest species richness and abundance of oribatid mites in the ABR, a finding supported by the PERMANOVA test and Table 2. The Shannon index showed a gradual increase with elevation, peaking at 2320 m in Layer 2 before a slight decline at 2500m in Layer 3. A study conducted on five elevational gradients of forest in North Carolina, USA, illustrated an increase in oribatid mite species richness at higher elevations (Lamoncha & Crossley, 1998). In contrast, research in the central Alps between 2050–2900 m a.s.l. indicated a decrease in the richness and abundance of oribatid mites with elevation (Fischer & Schatz, 2013). Similarly, a study in a tropical mountain in Malaysia, ranging from 700–3100 m a.s.l., demonstrated a decline in oribatid mite density and richness as elevation increased (Hasegawa et al., 2006). Moreover, in a tropical mountain rainforest in Ecuador spanning altitudes from 1850–2300 m, it was observed that the richness and densities of soil oribatid mites decreased as the elevation rose (Illig et al., 2010). A study in the Western Lesser Caucasus, Georgia, revealed a decrease in species richness and density of oribatid mites along an altitude gradient between 600–2200 m (Mumladze et al., 2015). Conversely, research in Mtirala National Park, Georgia, identified a bell-shaped distribution pattern of oribatid mites, with the highest species richness found in the mid-altitudes (Murvanidze & Arabuli, 2015). According to Hashemi Khabir et al. (2015), our research aligns with the increasing trend observed in the mountains of West Azerbaijan Province, Iran. The diversity pattern along elevation gradients is a complex and challenging subject, as noted by Peters et al. (2016). Factors such as sample bias, sample completeness, altitude range, edaphic factors, and vegetation can all impact the results when studying oribatid mites. As a result, different regions may offer contrasting descriptions of the diversity patterns of these mites along altitudinal gradients. Further research is necessary to provide a clearer understanding of this issue.

The species richness pattern and abundance of oribatid mites exhibited seasonal changes, as confirmed by the PERMANOVA test (Table 3). From July to the beginning of summer, there was a gradual decrease in species richness and the Shannon index. This decline may be attributed to the summer drought and decreasing moisture levels in the litter and soil (Taylor & Wolters, 2005). In conclusion, this study offers comprehensive data on biodiversity, community structure, and elevational and seasonal variations in species richness and abundance of oribatid mites within the Arjan Biosphere Reserve, located in Iran. Future research endeavours should prioritize completing the species inventory, assessing the impact of environmental factors, and identifying suitable indicator species within this protected area and other Iran regions.

## AUTHOR'S CONTRIBUTION

The authors confirm their contribution to the paper as follows: A. Iranpoor Parizi: Collecting, preparation and preliminary sorting of the material; M.A. Akrami: identification of specimens, writing and revising the manuscript; A. Mohammad-Khoramabadi and B. Heidari: writing and revising the manuscript. All authors participated in writing the paper. The authors read and approved the final version of the manuscript.

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## AVAILABILITY OF DATA AND MATERIAL

The specimens listed in this study are deposited in the Acarological collection of the Department of Plant Protection, School of Agriculture, Shiraz University, Shiraz, Iran and are available from the curator, upon request.

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study only included plants and arthropod material, and all required ethical guidelines for the treatment and use of animals were strictly adhered to in accordance with international, national, and institutional regulations. No human participants were involved in any studies conducted by the authors for this article.

## CONSENT FOR PUBLICATION

Not applicable.

## CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

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# بررسی تغییرات ارتفاع در ساختار و ترکیب جامعه کنه‌های اریباتید در ذخیره‌گاه زیست‌کره دشت ارژن، استان فارس، ایران

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**چکیده:** تغییرات در ساختار و ترکیب جامعه کنه‌های اریباتید در طول یک شیب ارتفاعی در ذخیره‌گاه زیست‌کره دشت ارژن در استان فارس (ایران) در سال ۱۳۹۴ مورد مطالعه قرار گرفت. داده‌ها از ۴۵ نمونه‌برداری ماهانه در سه لایه گیاهی از ارتفاع ۱۹۵۰ تا ۲۵۰۰ متر به دست آمد. داده‌ها با استفاده از روش آنالیز واریانس یک‌طرفه جایگشت (PERMANOVA) برای چگونگی توزیع ۸۹ گونه اریباتید در طول شیب ارتفاعی مورد تجزیه و تحلیل آماری قرار گرفتند. در مجموع ۱۲۶۴۸ عدد کنه اریباتید جمع‌آوری شد که منجر به شناسایی ۸۹ گونه متعلق به ۳۹ خانواده و ۵۳ جنس شد. یک تغییر قابل توجهی در توزیع کنه‌های اریباتید در لایه‌های مختلف ارتفاعی مشاهده شد. لایه ۲ بیشترین غنای گونه‌ای و فراوانی کل کنه‌های اریباتید را با ۶۷ گونه و ۶۱۶۲ فرد نشان داد و پس از آن لایه ۳ با ۶۲ گونه و ۴۳۵۹ فرد و لایه ۱ با ۵۹ گونه و ۲۱۴۰ فرد قرار گرفتند. گونه‌های غالب شامل *Jacotella frondeus* (Kulijev) و *Oribatula pallida* Banks در لایه ۱، *Pilogalumna tenuiclava* (Berlese)، *Aleurodamaeus* sp.3 و *J. frondeus* در لایه ۲ و *Aleurodamaeus* sp.3 و *J. frondeus* در لایه ۳ بودند. این مطالعه همچنین نشان داد که تنوع گونه‌های کنه‌های اریباتید به طور قابل توجهی در ارتفاعات بالاتر بیشتر است. علاوه بر این، نتایج اثر فصلی قابل‌توجهی را بر تنوع زیستی کنه‌های اریباتید با کمترین غنا و فراوانی گونه‌ای در تیر و شهریور نشان دادند.

**واژگان کلیدی:** شیب ارتفاع،کنه‌های سوسک‌مانند، تنوّع گونه‌ای، اکولوژی خاک