

Original article (Orijinal araştırma)

Arthropoda fauna of Zindan Cave (Isparta, Turkey) with notes on new records and some ecological characteristics¹

Zindan Mağarası (Isparta, Türkiye) Arthropoda faunası, yeni kayıtlar ve bazı ekolojik özellikler üzerine notlar

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Abstract

The aims of the study were to investigate the Arthropoda fauna of Zindan Cave (Aksu, Isparta Province, Turkey) and to consider some ecological characteristics of the collected species such as feeding habits, cave-dwelling categories, and zone distributions in caves. Twenty-seven species of Arthropoda were determined between May 2015 and December 2016, from Zindan Cave. The species found belong to the following orders: nine to Collembola, six to Coleoptera, five to Araneae, two to Diplopoda and one to Orthoptera, Trichoptera, Diptera, Trombidiformes and Isopoda. Nine species are endemic of Turkey. *Traegardhia distosolenidia* Zacharda, 2010 (Acari: Rhagidiidae) and *Folsomia asiatica* Martynova, 1971 (Collembola: Isotomidae) are newly recorded for the fauna of Turkey. The presence of *Heteromurus sexoculatus* Brown, 1926 (Collembola: Entomobryidae) in Turkey is confirmed. Twenty-four of the 27 species were from the dark zone and half of the collected species (6 troglobites and 8 trogloniles) are ecologically adapted to cave ecosystems. Species can be divided into three groups according to trophic preferences: 15 scavengers, 10 predators and two omnivores. Food habits, cave-dwelling categories, and zone distributions of collected species are discussed.

Keywords: Arthropoda, biospeleology, cave-dwelling categories, habitat, Zindan Cave

Öz

Çalışmanın amacı, Zindan Mağarası (Aksu, Isparta, Türkiye) Arthropoda faunasını belirlemek ve toplanan türlerin beslenme alışkanlıkları, ekolojik sınıflandırılması ve zon dağılımları gibi bazı ekolojik özelliklerini ortaya koymaktır. Zindan Mağarası'ndan Mayıs 2015 ile Aralık 2016 arasında 27 Arthropoda türü belirlenmiştir. Bu türlerden dokuzu Collembola, altısı Coleoptera, beşi Araneae, ikisi Diplopoda takımlarına ait iken, Orthoptera, Trichoptera, Diptera, Trombidiformes ve Isopoda takımlarına aittir. Bu türlerden dokuzu Türkiye için endemiktir. *Traegardhia distosolenidia* Zacharda, 2010 (Acari: Rhagidiidae) ve *Folsomia asiatica* Martynova, 1971 (Collembola: Isotomidae) türleri, Türkiye faunası için yeni kayıtlardır. Aynı zamanda Türkiye için *Heteromurus sexoculatus* Brown, 1926 (Collembola: Entomobryidae) varlığı doğrulanmıştır. Toplanan 27 türden yirmi dördü karanlık zondan ve türlerin yarısının (6 troglobit ve 8 troglonil) ekolojik olarak mağara ekosistemine adapte olduğunu ortaya konmuştur. Ayrıca türlerin trofik tercihlerine göre: 15 çöpcül, 10 predatör ve iki omnivor olmak üzere üç gruba ayrıldığı belirlenmiştir. Sonuç olarak, toplanan türlerin beslenme alışkanlıkları, ekolojik sınıflandırılması ve zon dağılımları tartışılmıştır.

Anahtar sözcükler: Arthropoda, biyospeleoloji, ekolojik sınıflandırılma, habitat, Zindan Mağarası

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Introduction

Cave ecosystems, with the relative simplicity of their communities, and the temporal and spatial isolation of their biota, are considered as natural ecological and evolutionary laboratories (Poulson & White, 1969). Cave-dwelling species help us to understand the differentiation of species in the biogeography and evolutionary process, as island biota (Cooper et al., 2007; Page et al., 2008; Juan et al., 2010).

Subterranean environments that are characterized by relatively stable abiotic conditions such as moisture, temperature, water chemistry and continuous darkness are unique ecosystems separated from the surface. These ecosystems are poor in food because of the mentioned features, and dependent on the food resources of the epigeal ecosystems (Hüppop, 2012). Bacteria, archaea and fungi are primary consumers of organic material (e.g., rotten wood and guano deposits) deposited in caves. Also, most Collembola and some Acari are attracted by colonies of decomposers. Invertebrates such as Isopoda, Diplopoda and some Coleoptera are consuming decayed organic material. These invertebrates also transfer of nutrients through fragmentation and foster microbial activity. Furthermore, these species in turn increases the rate of organic matter decomposition. Predators such as Chilopoda, Araneae, Pseudoscorpiones, carnivorous Acarina and some Coleoptera are hunting invertebrates which feed on dead organic material and microbes. Subterranean food webs mostly consist of more generalist species, as in soil food webs (Parimuchová et al., 2021).

Caves, which are one of the subterranean environments, are one of the most interesting earth formations on the planet. Thus, they have been studied for several aspects from past to present (Palmer, 1991). One of these study areas is biospeleology which studies living organisms in caves. Although the first study on cave organisms dates back to the seventeenth century in Europe (Romero, 2009) and cave-dwelling fauna of Europe and North America are particularly well known, in many parts of the world including Turkey, they are still poorly known (Juberthie & Decu, 1994; Peck et al., 1998; Kunt et al., 2010).

Turkey is defined as a "cave heaven" with about 40,000 caves (Nazik & Bayarı, 2018). However, only 1,250 of these are registered to the cave inventory of Turkey (Kopar, 2009; Nazik et al., 2005). In Turkey, the first biospeleological study was performed by Colonel Dr. Abdullah Bey at the Yarımburgaz Cave (Istanbul) in 1865 (Erguvanlı, 1975; Yamaç et al., 2021). Despite this early start, most of the biospeleological studies in Turkey has mostly continued through non-systematic sampling by foreign researchers until Kunt et al. (2010). Detailed studies of Turkish cave ecosystems have been available only recently (Aydin & Şen, 2020).

The number of terrestrial cave taxa of worldwide is estimated at over 21,000 species including more than 7,000 aquatic species (Juan et al., 2010). In addition, caves and other subterranean environments are poorly studied. In many regions of the world, cave-dwelling species still remain to be investigated (Gibert & Deharveng, 2002; Juan et al., 2010).

In studies conducted in Turkish caves, more than 200 invertebrates have been identified, 105 of which are endemic to Anatolia. More than 80% of the identified species were Arthropoda (Kunt et al., 2010; Antić et al., 2016). The reason for high endemism of the species living in the caves is that these species adapt to separated subterranean environments (Armas & Alayon Garcia, 1984; Juberthie & Decu, 1994). Although cave ecosystems have high endemism and rich fauna, there is still no detailed study on any cave fauna in Turkey (Kunt et al., 2010). Thus, the aims of the present study were (1) to determine the Arthropoda fauna of Zindan Cave, (2) to assign some ecological attributes of the collected species such as food habits, cave-dwelling categories and zone distributions, (3) to give some remarks on morphological characters linked to cave adaptation, and (4) to give notes on new records for Turkey.

Materials and Methods

Zindan Cave

Zindan Cave is located within the borders of the Aksu District of Isparta Province (37°48'42" N, 31°05'03" E) in the northern section of the Western Taurus Mountains. It was formed during the Resiyen (Upper Triassic period) and its length is 765 m (Bozcu, 2007). Although the cave is 765 m long; the last 265 m is dangerous for less-experienced cavers. Thus, only the first 500 m of the cave were investigated. The average temperature in the cave is 12-15°C, and the RH ranges from 80 to 85% between June and December.

Zindan Cave has been used by humans for sanctuary, dungeon, bat manure collection and tourism from A.D. 169-180 until the present. Today, the cave is used only for tourism. This cave, which has been exposed to humans in different time periods from the past to the present, is thought to have received the most damage when it was dedicated to tourism. With early contributions of Durmuş Kaya and Stephen Mitchell, the study of its biology has only recently recommenced. Zindan Cave, popular with tourists since 2003 and with sanctuary at the entrance, can be reached by a single arch bridge, from the Roman period, over Zindan Stream, a main branch of Köprüçay (Eurymedon) River (Kaya & Mitchell, 1985; Alp, 2013).

Zones of Zindan Cave

At the beginning of the study, the cave was divided into three zones based on the light intensity: entrance, twilight and dark zones. In first part of the cave to 30 m where light can easily reach was deemed the entrance zone. The part between 30-45 m where light breaks and creates a dim environment was deemed the twilight zone. The part from the end of the twilight to the end of the cave was deemed the dark zone.

Ecological classification of collected species

The ecological classification of the cave-dwelling species was made according to Barr (1968): accidental, troglaxene, troglophile and troglobite species. The classification of Barr (1968) was made by taking into consideration not only distribution and ecology but also the evolutionary adaptations of the species (Trajano, 2012). Rendoš et al. (2016) used an ecological classification method specific to the cave-dwelling Collembola. This classification is based on the proximity of habitats of the Collembola species to the surface. For the purposed of this study, the ecological classification of Ruffo (1957), which is primarily used by Italian speleobiologists (Sket, 2008), was also used. The troglomorphic properties of the species they identified were changed according to the method applied by Bar (1968).

Sampling

During 2015-2016, arthropod samples in Zindan Cave were determined monthly using three methods of collection: (1) careful searching over all cave surfaces (Di Russo et al., 2007), (2) extraction from organic matters (bat guano and vertebrate carcass), and (3) bolting water with plankton net (Kováč et al., 2005b). Samples were placed directly into tubes containing 70% ethanol. Cave animals are known to have extremely long generation times. Reproductive ability of cave-dependent species are slower than epigeal species, therefore, pitfall traps were not used. Also, the species richness in the cave ecosystems is limited because the cave ecosystems are separated from epigeal conditions. Therefore, identified and morphologically similar species were not collected in subsequent collection trips. However, the number and ecological information of these species were recorded. Sufficient sampling was made for diagnosis. Samples were lodged in the collection of the Biology Department of Süleyman Demirel University, Isparta, Turkey. Sampling was conducted by the first author who was equipped with both LED headlamp and a handheld lamp.

Results

Twenty-seven Arthropoda species were identified from Zindan Cave (Figure 1). Of these species, nine belong to Collembola, five to Araneae, six to Coleoptera, two to Diplopoda and one to Orthoptera, Trichoptera, Diptera, Trombidiformes and Isopoda. A complete list follows.

***Traegardhia distosolenidia* Zacharda, 2010 (Acari: Trombidiformes: Rhagidiidae)**

Material examined. 11.10.2015, ♀, 2 nymphs, dark zone. Det. Miloslav Zacharda.

General and Turkey distribution. The species was identified only from the Taquisara cave in Italy (Zacharda et al., 2010). This is a new record for Turkey.

Ecological classification and trophic behavior. Troglobite and predator.

Note. It was observed that they hunted Collembola specimens on the puddles in the cave and also, specimens were actively moving on the water surface.

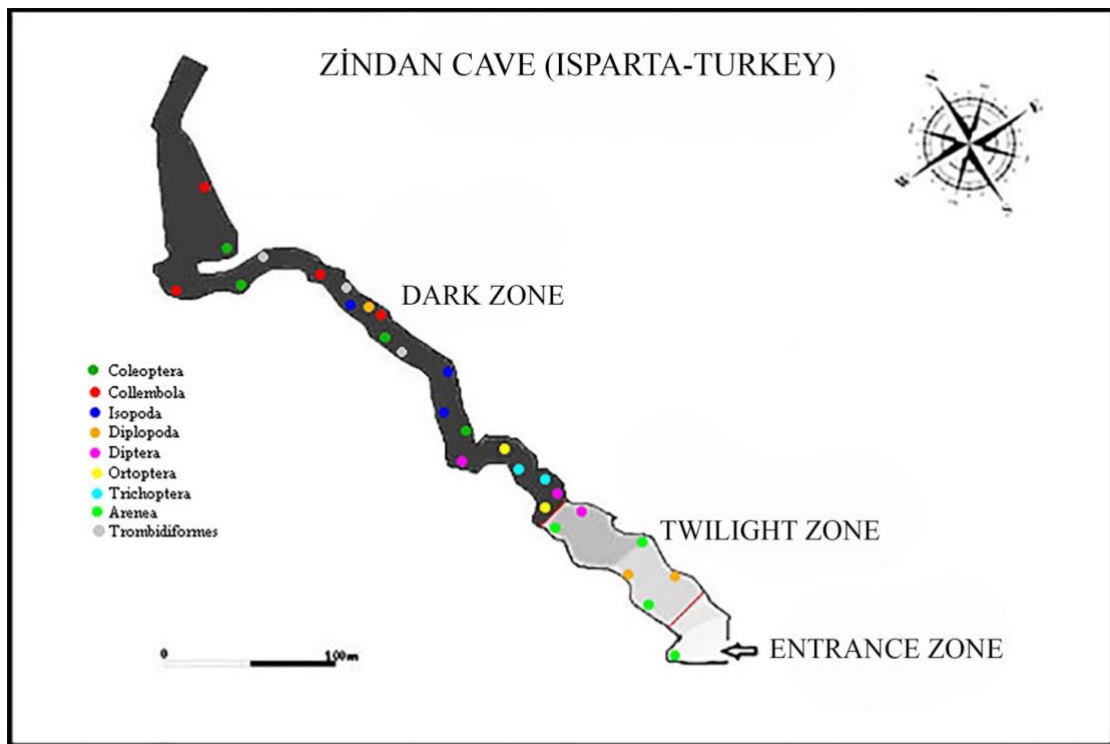


Figure 1. Zindan Cave and distribution of species according to zones (Modified from Karadem, 2011).

***Tegenaria percuriosa* Brignoli, 1972 (Arachnida: Araneae: Agelenidae)**

Material examined. 17.05.2015, 9♀♀, 5♂♂, twilight zone. Det. Kadir Boğaç Kunt.

General and Turkey distribution. Endemic to Turkey (Kunt et al., 2010). The type locality is Zindan Cave. Antalya Province, Dim Cave; Isparta Province, Barla Cave; Konya Province, Hacı Akif Cave; Sivas and Ankara Provinces, unknown localities (Kaya et al., 2010).

Ecological classification and trophic behavior. Troglophile and predator.

Note. It is reported that an adult male of this species has previously been found on the wall surface at the 30-50 m of the cave (Gasparo, 2007). It was observed that this species feed on the *Limonia nubeculosa* Meigen, 1804 (Diptera: Limoniidae) specimens.

***Maimuna vestita* (C.L.Koch, 1841) (Arachnida: Araneae: Agelenidae)**

Material examined. 17.05.2015, 3♂♂, transition zone. Det. Kadir Boğaç Kunt.

General and Turkey distribution. East Mediterranean (Vrenozi & Jäger, 2012). Aydın, Bursa, Istanbul, Izmir, Muğla Provinces (Brignoli, 1978; Kaya & Uğurtaş, 2007).

Ecological classification and trophic behavior. Troglaxene and predator.

Note. This species is also known from epigeal ecosystems. It especially lives in rocky habitats (Kaya & Uğurtaş, 2007). It was observed that the specimens built their webs near or under the stones in the cave. The main food sources of the species are small Diptera species.

***Metellina mengei* (Blackwall, 1870) (Arachnida: Araneae: Tetragnathidae)**

Material examined. 16.06.2016, 7♀♀, 2♂♂, dark zone. Det. Kadir Boğaç Kunt.

General and Turkey distribution. It distributes from Europe to Georgia (Marusik et al., 2012). Antalya, Bilecik, Bursa and Çankırı Provinces (Marusik et al., 2012).

Ecological classification and trophic behavior. Troglophile and predator.

Note. This species lives on leaf litter in meadows and woodlands, but has also been recorded in caves (Marusik et al., 2012).

***Diplocephalus turcicus* Brignoli, 1972 (Arachnida: Araneae: Linyphiidae)**

Material examined. 15.09.2016, 2♀♀, 3♂♂, dark zone. Det. Kadir Boğaç Kunt.

General and Turkey distribution. Greece (Deltshv, 2008) and Turkey (Kunt et al., 2010). Burdur Province, İnsuyu Cave; Isparta Province, Zindan Cave; Konya Province, Hacı Akif Cave (Brignoli, 1972; Kunt et al., 2010).

Ecological classification and trophic behavior. Troglophile and predator.

Note. This species was observed that they are hunting on Guano.

***Lepthyphantes leprosus* (Ohlert, 1865) (Arachnida: Araneae: Linyphiidae)**

Material examined. 15.09.2016, 3♀♀, ♂, twilight zone. Det. Kadir Boğaç Kunt.

General and Turkey distribution. Bulgaria, Macedonia, Serbia, Croatia, Albania, Greece, Turkey (Deltshv, 2008). Bitlis Province, Sultan Seyit Cave; Diyarbakır Province, Korkha Cave (Kunt et al., 2010).

Ecological classification and trophic behavior. Troglophile and predator.

Note. Although species of *Lepthyphantes* have been reported from various caves (Mammola et al., 2018; Prokopenko, 2019), this species is considered as troglophile in this study because of its dependence on the epigeal ecosystems.

***Eurygyrus bilseli* (Verhoeff, 1940) (Diplopoda: Callipodida: Schizopetalidae)**

Material examined. 16.06.2015, 26.09.2015, 11.10.2015, 4♀♀, 3♂♂, twilight and dark zone. Det. Dragan Antic and Henrik Enghoff.

General and Turkey distribution. Endemic to Turkey (Enghoff, 2006). Burdur Province, İnsuyu Cave; Isparta Province, unknown locality; Konya Province, Hacı Akif Cave; Tınaztepe Cave; Mersin Province, Cennet Cave (Enghoff, 2006; Kunt et al., 2010).

Ecological classification and trophic behavior. Troglaxene and scavenger.

Note. The species was observed that it was active in darkness. At night, specimens were seen extensively around the stream bed outside the cave.

***Mesoiulus taurus* Antic, 2016 (Diplopoda: Julida: Julidae)**

Material examined. 17.06.2015, 26.09.2015, 11.10.2015, 15.12.2015, 17.05.2016, 4♀♀, 2♂♂, dark zone. Det. Dragan Antic and Henrik Enghof.

General and Turkey distribution. Endemic to Turkey. The type locality is Zindan Cave. There are four endemic *Mesoiulus* species distributed in Turkish caves including this species. The three others are *Mesoiulus ciliciensis* Strasser 1975 from Mersin Province, *Mesoiulus kosswigi* Verhoeff, 1936 from Istanbul Province and *Mesoiulus turcicus* Verhoeff, 1898 from Bilecik Province (Enghoff, 2006).

Ecological classification and trophic behavior. Troglobite and scavenger.

Note. This species is distributed between 200-400 m into the cave. Many of specimens were collected on the moss formed under the projector used for lighting 250 m into the caver.

***Trichonethes kosswigi* (Strouhal, 1953) (Malacostraca: Isopoda: Trichoniscidae)**

Material examined. 16.06.2015, 11.10.2015, 17.05.2016, 4♀♀, 3♂♂, dark zone. Det. Stefano Taiti.

General and Turkey distribution. This species is endemic to Turkey and the type locality of the species is Zindan Cave (Argano & Manicastro, 1988). Antalya Province, Damlatas Cave and Indađı Cave; Burdur Province, Insuyu Cave; Isparta Province, Barla Cave and Inönü Cave; Konya Province, Su Çıktıđı Cave, Tinaztepe Cave; Hacı Akif Cave, Child Thrown Hole Cave, Körükini Cave and Asarini Cave (Argano & Manicastro, 1988).

Ecological classification and trophic behavior. Troglobite and scavenger.

Note. This species is a troglobite species due to lack of eyes, reduced pigment and a completely whitish structure. This species lives between 150 and 300 m into the cave. This species was observed that they feed on guano, organic residues and carrion.

***Lipothrix lubbocki* (Tullberg, 1872) (Entognatha: Collembola: Sminthuridae)**

Material examined. 11.10.2015, ♀, dark zone. Det. Igor Kaprus.

General and Turkey distribution. The species distributes throughout Europe (Popa & Šustr, 2017). This species is also reported from North Africa (Popa, 2012). The species was only known from Ordu Province in Turkey (Özata, 2015).

Ecological classification and trophic behavior. Accidentally and scavenger.

Note. This species is known that the species occurs in forests, especially pine forests (Kováč et al., 2005a). Thus, the presence in the cave was accidental.

***Lepidocyrtus lignorum* (Fabricius, 1793) (Entognatha: Collembola: Entomobryidae)**

Material examined. 11.10.2015, 2♀♀, dark zone. Det. Igor Kaprus.

General and Turkey distribution. Holarctic Region (Dányi & Traser, 2008). Forest habitats in Antalya Province (Sevgili & Özata, 2014).

Ecological classification and trophic behavior. Troglaxene and scavenger.

Note. This species is known that the species lives in the meadows and pastures (Komonen & Kataja-Aho, 2017). Thus, the presence in the cave was accidental.

***Heteromurus sexoculatus* Brown, 1926 (Entognatha: Collembola: Entomobryidae)**

Material examined. 11.10.2015, 8 specimens, dark zone. Det. Igor Kaprus.

General and Turkey distribution. Romania, Israel, Iran, Iraq and Rhodes Island (Greece) (Ellis, 1974; Shayanmehr et al., 2013). The presence of the species in Turkey was doubtful according to Sevgili & Özata (2014). An exact locality of the species is the first to be provided through this study. Thus, the presence of the species in Turkey is confirmed.

Ecological classification and trophic behavior. Troglophile and scavenger.

Note. Shayanmehr et al. (2013) reported that the species distributed on leaf litter and soil in Iran. Species probably occurs in dark and humid habitats.

***Pseudosinella horaki* Rusek, 1985 (Entognatha: Collembola: Entomobryidae)**

Material examined. 11.10.2015, 4 adults, dark zone. Det. Igor Kaprus.

General and Turkey distribution. Slovakia, Hungary, Moldova, Czech Republic and Turkey (Dániel & Nándor, 2012). In a study conducted in Ordu Province, the species was reported from pine and spruce forest-floor debris and localities over 1,300 m (Özata et al., 2017).

Ecological classification and trophic behavior. Troglaxene and scavenger.

Note. This species is known that the species distributes under-forests such as *Larix decidua* Mill., *Picea abies* (L.) H. Karst. and *Pinus sylvestris* L. (Özata et al., 2017; Čuchta et al., 2019). Thus, the presence in the cave was accidental.

***Folsomia asiatica* (Martynova, 1971) (Entognatha: Collembola: Isotomidae)**

Material examined. 11.10.2015, 12 specimens, dark zone. Det. Igor Kaprus.

General and Turkey distribution. Azerbaijan, Tajikistan, Iran (Rad & Morteza, 2015). This is a new record for Turkey.

Ecological classification and trophic behavior. Troglophile and scavenger.

Note. This species is reported to be linked to hypogenous life due to the lack of pigment and eyes. However, Rad & Morteza (2015) reported the species from soil and leaf litter under oak trees (*Quercus infectoria* G.Olivier) from Iran. So, it is considered to be a troglophile species.

***Folsomia penicula* Bagnall, 1939 (Entognatha: Collembola: Isotomidae)**

Material examined. 11.10.2015, 2 specimens, dark zone. Det. Igor Kaprus.

General and Turkey distribution. Palearctic region (Potapov, 2001). The species has been reported from the Turkey-Syria border (Sevgili & Özata, 2014). Özata et al. (2017) reported it from forest habitat from Ordu Province.

Ecological classification and trophic behavior. Accidental and scavenger.

Note. The general habitat of the species is tree debris in forests (Shayanmehr et al., 2013). The species, which is generally epigenous was collected from algae in 300 m into the cave.

***Folsomia manolachei* Bagnall, 1939 (Entognatha: Collembola: Isotomidae)**

Material examined. 11.10.2015, 8 specimens, dark zone. Det. Igor Kaprus.

General and Turkey distribution. Europe and Asia (Potapov, 2001). This species has been only reported from Ordu Province (Özata et al., 2017).

Ecological classification and trophic behavior. Accidental and scavenger.

Note. The general habitat of the species is forests and meadows (Raschmanová et al. 2017). The species, which is epigene, was collected in a small puddle 350 m into the cave. Also, it was collected on the algae in the cave.

***Isotomiella minor* (Schäffer, 1896) (Entognatha: Collembola: Isotomidae)**

Material examined. 11.10.2015, 11 specimens, dark zone. Det. Igor Kaprus.

General and Turkey distribution. Europe (Folsom, 1932). This species is also a cosmopolitan species (Potapov, 2001; Özata et al., 2017). Antalya (Sevgili & Özata, 2014) and Ordu (Özata et al., 2017) Provinces.

Ecological classification and trophic behavior. Troglaxene and scavenger.

Note. This species is reported that the species lives on leaf litter and soil in Iran (Shayanmehr et al., 2013). The species, which is epigene, was collected in a small puddle 400 m into the cave. Species probably occurs in dark and humid habitats.

***Parisotoma notabilis* (Schäffer, 1896) (Entognatha: Collembola: Isotomidae)**

Material examined. 11.10.2015, 3 adults, dark zone. Det. Igor Kaprus.

General and Turkey distribution. Europe (Porco et al., 2012). Turkey-Syria border (Sevgili & Özata, 2014; Özata et al., 2017). The species is widespread and common in Ordu Province (Özata et al., 2017).

Ecological classification and trophic behavior. Troglaxene and scavenger.

Note. The general habitat of the species is tree debris in forests and meadows, but also it is typically present in arable fields, pastures, urban soils and caves (Shayanmehr et al., 2013; Von Saltzwedel et al., 2017). The species, which is epigene, was collected in a small puddle 350 m into the cave. It is assumed that the species can live in many habitats and is also adapted to cave habitats.

***Agabus dilatatus* (Brullé, 1832) (Insecta: Coleoptera: Dytiscidae)**

Material examined. 16.06.2015, 11.10.2015, 16.05.2016, 4♀♀, 3♂♂, dark zone. Det. Mustafa Darilmaz.

General and Turkey distribution. Europe: Albania, Bulgaria, Georgia, Greece, Italy, Macedonia, Russia (South Territory), Turkey, Ukraine. North Africa: Algeria, Egypt, Morocco, Tunisia. Asia: Cyprus, Iran, Iraq, Israel, Kyrgyzstan, Lebanon, Sinai, Syria, Turkey, Uzbekistan (Vafaei et al., 2009; Scheers & Thant, 2017). Adana, Ankara, Bursa, Gümüşhane, Isparta, İzmir, İzmit, Konya, Rize, Trabzon and Van Provinces (Kıyak et al., 2007).

Ecological classification and trophic behavior. Accidental in caves and predator (Karaman, 2007; Özgenç, 2011).

Note. Specimens were collected from ponds and puddles 280 m into the cave. This species is known to live in groundwater (Karaman, 2007; Özgenç, 2011). The specimens may have been accidentally transported by groundwater to the cave. The species was observed with *Agabus biguttatus* (Olivier, 1795) in the same water sources.

***Agabus biguttatus* (Olivier, 1795) (Insecta: Coleoptera: Dytiscidae)**

Material examined. 16.06.2015, 11.10.2015, 16.05.2016, 3♀♀, 2♂♂, dark zone. Det. Mustafa Darilmaz.

General and Turkey distribution. Species is widely distributed in Europe, North Africa and Asia (Kıyak et al., 2007; Vafaei et al., 2009; Özgenç, 2011). Adana, Aksaray, Ankara, Bilecik, Bursa, Çankırı, Elazığ,

Gaziantep, Gümüşhane, Isparta, İzmir, Kastamonu, Sakarya, Trabzon and Yozgat Provinces (Darılmaz & Kiyak, 2006; Kiyak et al., 2007).

Ecological classification and trophic behavior. Accidental in caves and predator (Karaman, 2007; Özgenç, 2011).

Note. The specimens were collected from the ponds and puddles 280 m into the cave. The species are known to live in groundwater (Karaman, 2007; Özgenç, 2011). The specimens may have been accidentally transported by groundwater to the cave. These species were observed with *A. dilatatus* in the same water sources.

***Choleva (Cholevopsis) bertiae* Giachino & Vailati, 2000 (Insecta: Coleoptera: Leiodidae)**

Material examined. 17.05.2015, 16.07.2015, 11.10.2015, 15.12.2015, 28.02.2016, 16.06.2016, 15.09.2016, 3♀♀, 4♂♂, dark zone. Det. Michel Perreau.

General and Turkey distribution. Endemic to Turkey. Isparta Province, Zindan Cave; Eskişehir Province, Sarkaya Cave Tütüncüni Cave; Antalya Province, Zeybeyni Cave; Antakya Province, unknown locality (Fidan et al., 2014).

Ecological classification and trophic behavior. Troglobite and scavenger.

Note. This species was observed that *Choleva* specimens were feeding a variety of foods such as bat guano, dead bats and mice.

***Pisidiella spatulifera* Jeannel, 1930 (Insecta: Coleoptera: Leiodidae)**

Material examined. 16.06.2015, 16.07.2015, 11.10.2015, 15.12.2015, 28.02.2016, 15.09.2016, 5♀♀, 6♂♂, dark zone. Det. Michel Perreau.

General and Turkey distribution. Endemic to Turkey. Isparta Province, Zindan Cave; Konya Province, Hacı Akif Cave (Jeannel, 1955).

Ecological classification and trophic behavior. Troglobite and scavenger.

Note. This species was observed that *Pisidiella* specimens were feeding a variety of foods such as bat guano, dead bats and mice in small groups. Although their eyes are completely blind, they are very sensitive to light and other senses have developed.

***Pisidiella ovoidea* Jeannel, 1955 (Insecta: Coleoptera: Leiodidae)**

Material examined. 16.06.2015, 3♀♀, 4♂♂, dark zone. Det. Michel Perreau.

General and Turkey distribution. Endemic to Turkey. Isparta Province, Zindan Cave (Jeannel, 1955).

Ecological classification and trophic behavior. Troglobite and scavenger.

Note. This species was observed that *Pisidiella* specimens were feeding a variety of foods such as bat guano, dead bats and mice in small groups. Although their eyes are completely blind, they are very sensitive to light and other senses have developed.

***Quedius magarasiensis* Bordoni, 1978 (Insecta: Coleoptera: Staphylinidae)**

Material examined. 15.09.2016, 3♀♀, 4♂♂, dark zone. Det. Sinan Anlaş.

General and Turkey distribution. Endemic to Turkey. The type locality is Zindan Cave (Bordoni, 2010; Kunt et al., 2010).

Ecological classification and trophic behavior. Troglophile and predator.

Note. The presence of the species in the cave depends on guano. If there are no guano, they will absent in the cave. Although the distribution of the species in the cave is the dark zone, it is the possible to reach them in every area where bat roosts exist, as guano provides the food cycle of this species in the cave.

***Limonia nubeculosa* Meigen, 1804 (Insecta: Diptera: Limoniidae)**

Material examined. 16.06.2015, 2♀♀, 3♂♂, dark zone. Det. Hasan Koç.

General and Turkey distribution. This species is distributed throughout the Palearctic Region, and also in the Nearctic Region (Canada, USA) (Driauach & Belqat, 2016). Aydın, Denizli, Eskişehir, Isparta and Muğla Provinces, and European part of Turkey (Özgül et al., 2009; Bilgin et al., 2015).

Ecological classification and trophic behavior. Troglaxene and omnivore.

Note. The species, which can be observed in the various habitats at aboveground environments, is very common in cave environments during the winter and summer seasons (Barnes et al., 2009). The species feed on insects, carrions, guano and plant residues in caves. Also, it is a food source for cave spiders (Manenti et al., 2015).

***Troglophilus adamovici* Us, 1974 (Insecta: Orthoptera: Rhabdophoridae)**

Material examined. 15.12.2016, ♀, twilight and dark zone. Det. Mehmet Sait Taylan.

General and Turkey distribution. Endemic to Turkey (Taylan, 2011). The type locality is Zindan Cave. Konya Province, Balatini Cave, Körükini Cave, Ferzene Cave, Tınaztepe Cave (Rampini & Di Russo, 2003; Kunt et al., 2010).

Ecological classification and trophic behavior. Troglophile and predator.

Note. This species was collected from 150 m into the cave. Also, this species is dependent on food resources of the epigeal ecosystems.

***Stenophylax nycterobius* McLachlan, 1875 (Insecta: Trichoptera: Limnephilidae)**

Material examined. 25.09.2015, 11.10.2015, 5 larvae and 2♀♀, 2♂♂, dark zone. Det. Füsün Sipahiler.

General and Turkey distribution. The species is distributed very widely in Europe (Ibrahimi et al., 2013). Also, this species is known from Monte Cucco Cave from Italy (Corallini & Marchetti, 2016). Although the species is reported in the Central Anatolia, Turkey, there is no exact locality record (Moretti & Gianotti, 1964).

Ecological classification and trophic behavior. Troglaxene and omnivore.

Note. It is reported that this species uses caves for diapause during the summer (Malicky & Winkler, 1974). It was observed that the species completed all developmental stages in the cave. Larvae are omnivorous shredders. They feed on particulate organic matter and by hunting aquatic invertebrates. The larvae living in puddles inside the cave make their structures by using materials in the cave and they are different from the aboveground environment. Also, the larvae were seen under the drops flowing from the stalactites in the parts where there was no water. It was observed that the movements of Trichoptera adults slowed down due to the low temperature of the cave.

Discussion

In this study, 27 arthropod species were collected. Kunt et al. (2010) reported eight species, six of which are endemic (E) to Turkey, from Zindan Cave. These species were *T. percuriosa* (E), *Harpactocrates troglophilus* Brignoli, 1978 (Arachnida: Araneae: Dysderidae) (E), *D. turcicus*, *C. bertiae* (E), *Q. magarasiensis* (E), *T. adamovici* (E), *Cylisticus convexus* (De Geer, 1778) (Malacostraca: Isopoda: Cylisticidae), *T. kosswigi* (E). However, Kunt et al. (2010) overlooked two endemic Leiodidae species *P.*

spatulifera and *P. ovoidea* mentioned by Jeannel (1955) from the cave. Thus, 10 species, eight of which are endemic to Turkey, were previously known from the cave (Jeannel, 1955; Kunt et al., 2010). In the present study, *C. convexus* and *H. troglophilus* species were not collected. Probably *C. convexus* was previously collected accidentally, given that it is known from Europe and Northern Asia (excluding China), North America and South America. *Harpactocrates troglophilus* has been described from Zindan Cave. However, the species were found in mesovoid shallow substratum traps outside the cave (personal observation). Also, Kunt et al. (2019) described a new genus (*Kut* gen. nov.) with the type species *H. troglophilus*. They reported that the species was probably not present in Zindan Cave and they also collected the species from Kurucaova Village (Konya Province) which is outside of the cave ecosystem. Therefore, the presence of the species in the cave is questionable. In addition, new data has showed that nine species are endemic for Turkey and *M. taurus* has recently been given as a new species from the cave. Based on these data, Zindan Cave is the type locality of *M. taurus*, *P. ovoidea* and *Q. magarasiensis*.

It was observed that most of collected species (24 of 27 species) occurred in the dark zone. Of the rest, two of them were in the twilight zone, one in a transition zone and two species were in both the twilight and dark zones. In addition, half of the collected species (6 troglobites and 8 troglophiles) are ecologically adapted to the cave ecosystem while the other half (8 troglonexes and 5 accidental species) were not ecologically adapted. Also, the results show that the species are divided into three groups according to trophic behavior: 15 scavengers, 10 predators and only two omnivore species (*L. nubeculosa* and *M. nycterobia*) (Manenti et al., 2015).

As a result of the present study, it has been determined that more than 33% of the collected species are endemic to Turkey. Zindan Cave is the type locality of *M. taurus* and the species is only known from this cave. Also, *T. distosolenidia*, *H. sexoculatus* and *F. asiatica* are firstly reported from Turkey. Especially, *T. distosolenidia* has an interesting distribution pattern with distribution in Italy and Turkey.

Zindan Cave continues be used for tourism, which can be hazardous both for the cave and the cave-dwelling organisms. Warm lighting for tourism activities constitutes the biggest problem in the cave. These problems are: (1) algae are growing in the artificially lit areas, (2) various formations as stalactites, stalagmites and columns inside the cave are damaged by algae, (3) owing to tourism and lighting, populations of bats in the cave are decreasing because baby bats are stressed and fall from their roosts, (4) warm lighting is thought to threaten especially troglobite and troglophile species which are adapted to the cave. Lighting also causes accidental species to penetrate deeper into the cave.

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