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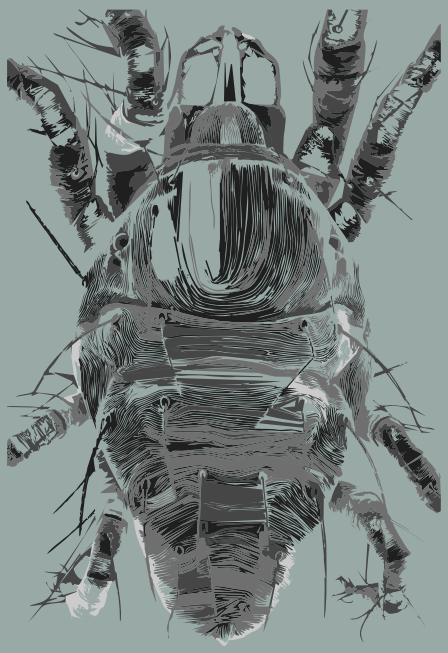

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REVIEW

Capturing migratory birds and examining for ticks (Acari: Ixodida)

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ABSTRACT: Ticks (Acari: Ixodida) are hematophagous ectoparasites of a wide variety of mammals, birds, reptiles, and amphibians, and are the vectors of many pathogenic agents, such as bacteria, protozoa, and viruses. The seasonal movement and migration of birds is one of the main causes of the dispersal of ticks and tick-borne pathogens. Therefore, identification of ticks associated with migratory birds is a fundamental step to understand the ecology of ticks infesting birds and evaluate their potential as vectors of zoonotic diseases. In this article, we provided a brief review for capturing migrating birds and examining them for ticks.

Keywords: Ixodidae, Argasidae, migrating birds, capturing, Turkey.
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INTRODUCTION

Wild birds are an important reservoir of several tick-borne viral and bacterial agents such as *Anaplasma phagocytophilum*, *Borrelia* spp., *Coxiella burnetii*, *Rickettsia* spp., and Crimean-Congo hemorrhagic fever virus (Dubska et al., 2009; Ogrzewalska et al., 2009; Elfving et al., 2010; Luz et al., 2012; Keskin et al., 2014; Leblebicioglu et al., 2014; Horak et al., 2018). Migratory birds, play a major role in the transportation of ticks to short or long distances (Hoogstraal et al., 1961; Dietrich et al., 2011; Wallménius et al., 2014), allowing ticks to establish in new areas, though resident birds can also contribute to the dispersion of ticks and tick-borne pathogens (Schneider et al., 2015; Roselli et al., 2020). To understand the eco-epidemiology of various diseases, it is important to study the interactions between ticks, their hosts, pathogens, and their biotic and abiotic environments.

There is a variety of methods to sample free-roaming ticks or ticks from hosts and the choice of a specific method depends on the aim of the surveillance. Ticks can be collected directly from the host animal (alive or hunter-killed, road-killed or dead found), or by dragging/flagging techniques from the vegetation, as well as by examining the nest material of the host animal. In addition, ticks could be collected by CO_2 traps and pheromone traps. Selection of incorrect season, location, and timing could end up with inaccurate sampling (Estrada-Peña et al., 2017).

Capturing migratory or resident birds and examining them for ticks is one of the methods to study the ecology of these ectoparasites and the pathogenic microorganisms they might transmit (Hoogstraal et al., 1961; Ralph et al., 2004; Dubska et al., 2009; Elfving et al., 2010; Keskin and Erciyas-Yavuz, 2019). Long term ringing stations are of paramount importance to study the migration ecology of birds, but also their ectoparasites. In order to study the tick species and their developmental stages found on birds, a collaboration with ornithologists is of utmost importance.

Capturing the birds

Birds are under protection of the local conservation agencies in many countries of the world, and accordingly ringers should have a legal license and ringing permit. Moreover, in principle legal sellers cannot provide mist nets to people who do not have a license. Ringers are responsible for the safety and welfare of the birds and should conduct their studies under the Ethical Principles in Animal Research and Welfare, which was approved by Animal Ethical Committees.

In order to capture birds, mist nets (Fig. 1), walk-in traps, swim-in traps, funnel traps, clap traps, dip nets, whoosh nets, cannon nets, and nooses are some of the used methods. Mist nets are widely used to catch a high variety of birds within a short period of time and little effort (Dunn and Ralph, 2004a).

Nets should be placed with good trapping probability along a reasonably long control path. It takes some practice to optimize a new location. If the catching area holds active diurnal migration of birds, the mist nets should be placed according to their passage direction. Depending on the catching sites characteristics as wetland, woodland, valley or along a river the mist nets should be placed in front of the optimal feeding vegetation which is expected to increase their capture probability. Nets can be placed in singles or connected in rows. When placed in suitable habitats, these nets are practically invisible for many

Figure 1. A. Erected mist net in Cernek bird ringing station, **B.** Caught birds in mist net, **C.** A Garden Warbler, *Sylvia borin*, captured by mist net.

birds, resulting with a high capture rate. They are easily transported and can be set up in a variety of habitats. Depending on the species composition, the effective usage of mist nets is related to the habitat selection to erect the mist nets in the study area, and on the correctly selected character of the mist nets (e.g. thinner nets with optimal mesh size, height and length). Mist nets differ in height, length, mesh size, shelve number, thread material and thread thickness. Mist nets have shelves created by horizontally lines that create a flabby and baggy pocket. When a bird hits the net, it falls into this pocket and mainly the wings, head and feet become tangled. The characteristics of the used mist nets will depend on the species composition at the study area, the species-specific sampling target, the habitat of catching, the team (if staff of the station consists of well trained volunteers, easy to extract entangled birds from thinner nets). Small birds can be captured with small mesh size (16-38 mm); whereas larger birds can be captured using large size mesh sizes (45-60 mm). A dho-gaza is a type of mist net that can be used for larger birds, such as raptors.

Required materials for the mist net setting up: Poles (for a standard 2 or 2,5 meter high nets 3-4 m long): can be produced from cane, bamboo (light, durable, long and suitably robust as mist net poles), wood (often dowel) or metal (preferably aluminum); vegetation chopping equipment; bird-bags, holding bags or paper bags; pegs; and string. Bird bags are used to put extracted birds from mist nets, to transport them safely and to temporarily store them while they are waiting for ringing and investigation. Detailed description of mist netting can be found in the publications of Busse & Meissner (2015) and Beer et al. (2001). Different sized polyester or nylon mist nets

can be purchased, e.g., Japanese (Japan), Avinet (USA), and Ecotone (Poland). Having chosen a suitable mist netting site, the mist net is set up as indicated by Gosler (2004), Busse and Meissner (2015) and DBCA (2017).

Major advantages of using mist nets are; (1) low visibility by birds, (2) ease of standardized sampling, (3) relatively free of observer effects due to standardized catching effort, (4) ability to detect species that are often missed using other traps, (5) better statistical analysis of the data by capturing-recapturing birds, (6) opportunity to examine for ectoparasites and diseases of birds, and (7) capture large number of birds with less effort (Dunn and Ralph, 2004; Ralph et al., 2004).

Disadvantages of using mist nets can be; (1) captured birds are at risk of injury or death from predators, (2) exposure to handling or temperature stress, which could be avoided by checking the nets every 30-40 min, (3) learning and avoiding the locations of nets by resident birds. These disadvantages are also distinctive in other catching methods, and the most proper catching method selection will increase the catching performance in relation to the targeted species.

Every captured bird is ringed, which allows to follow up recaptured birds. Bird ringing is an important tool to study birds' ecology, behavior, movements, dispersal, breeding productivity and population change (Baillie et al., 2007; Robinson et al., 2014).

Time and duration of bird capturing and ringing depends on the aim of the study. When targeting migratory birds which are playing an important role in dispersal of ticks and tick-borne diseases, spring and autumn migration seasons are the most appropriate period for passerines, whereas late autumn and early winter would also be important study period for water birds. If resident birds are targeted for the study of ticks and the pathogens they might transmit, the capturing could be done at any time of the year.

Captured birds are transferred within a holding bag to a ringing station, where they are identified, aged and sexed, and then marked with a uniquely coded metal ring (aluminum or steel), and morphometric measurements (such as wing length, tarsus length, and weight) are recorded and thereafter they are released. Re-trapped birds with rings from the same season are checked again only for fat, muscle and weight changes, while re-trapped birds from different years are treated like first capture birds and all measurements are taken again. The ringer rings and takes all the measurements, while a second person, called the writer, notes all dictated data in the bird ringing protocol.

Collection and identification of ticks

One column at the bird ringing protocol can be generated for the tick recording. While writing the species code, ring code, date, measurements etc., the ringer dictates the writer the number of ticks extracted from examined birds. It is easier to follow up later all the needed information about the bird and ringing details from the bird ringing protocol, than having the ticks' information in a separate form. It is important to record all the birds which have been checked for ticks, including those on which no ticks could be found, in which case a zero should be placed instead of leaving the line blank in the protocol. The number of extracted ticks should be written in the line of the examined species. The writer has to wait until the ringer dictates the total number of extracted ticks, in some birds it is possible to extract several tens of ticks (e.g. a max. of 220 ticks from one Common Blackbird, 163 ticks extracted from one Great Tit, 68 ticks extracted from one European Robin extracted at Cernek Ringing Station).

To ensure minimal stress to the birds, ticks should be collected from birds at a minimum time. Ticks on birds usually attach to base of the beak, ears, eye rims, neck, upper breast and nape (Apanaskevich and Oliver Jr, 2014), however the surrounding of the cloaca, back, belly, and throat of the birds should also be inspected for ticks (Fig. 2). During the examination of the bird, in order to avoid possible escapes from hand, the widely used ringer's grip or the photographer's grip is recommended (De Beer et al., 2001). It was shown that the body part of the tick infestation, may vary among tick species, while some ticks may be found on different parts of the body other than the head (Roselli et al., 2020). If time permits, the bird's whole body should be examined for ticks. If that is not possible, the examined parts must be mentioned in every study. To better visualize the ticks, blowing directly to the feathers and the skin of the bird, could be of help (Fig. 3). A binocular head loupe can be also recommended for collectors of bird ectoparasites. It is especially difficult to detect the un-engorged immatures (larvae and nymphs) in birds with scurf (e.g., *Cettia cetti*). If a bird is recaptured soon after first capture, it should be checked again for the presence of new ticks or because immatures might have developed to the next stage in the meantime.

Ticks are usually removed with the help of a fine forceps or tick hooks and placed in suitable vials with specific content depending on the study aim. To perform just systematic studies to identify the tick species of a location, site or country the ticks can be transferred alive in vials with a piece of grass to provide humidity. Targeting DNA studies of the tick specimens, the ticks are mostly preserved in 70% ethyl alcohol, storage at -20 ^{0}C or freezing at -70 ^{0}C. These specimens can be stored up to two years successfully in ethyl alcohol, which is better than dry storage. Ticks that will be tested for the presence of any pathogenic agents should be placed in absolute ethanol. For RNA virus studies, stabilized buffer (RNAlater) is usually used for storage, where the ticks should be completely submerged in buffer and later stored at -20 ^{0}C (Estrada-Peña et al., 2017). All vials should be labelled with the name of host species, ring number, and collection date. For birds with long scientific names, standardized (5 or 6 alpha codes of bird species) code could be used as abbreviations, e.g. SYATR for *Sylvia atricapilla* and TUMER for *Turdus merula* (Busse, 2000; Busse and Meissner, 2015). At Cernek Ringing Station (41°36 N, 36°05 E), the five alpha code is used, where the first two letter indicate the genus, while the last three letters those of the species

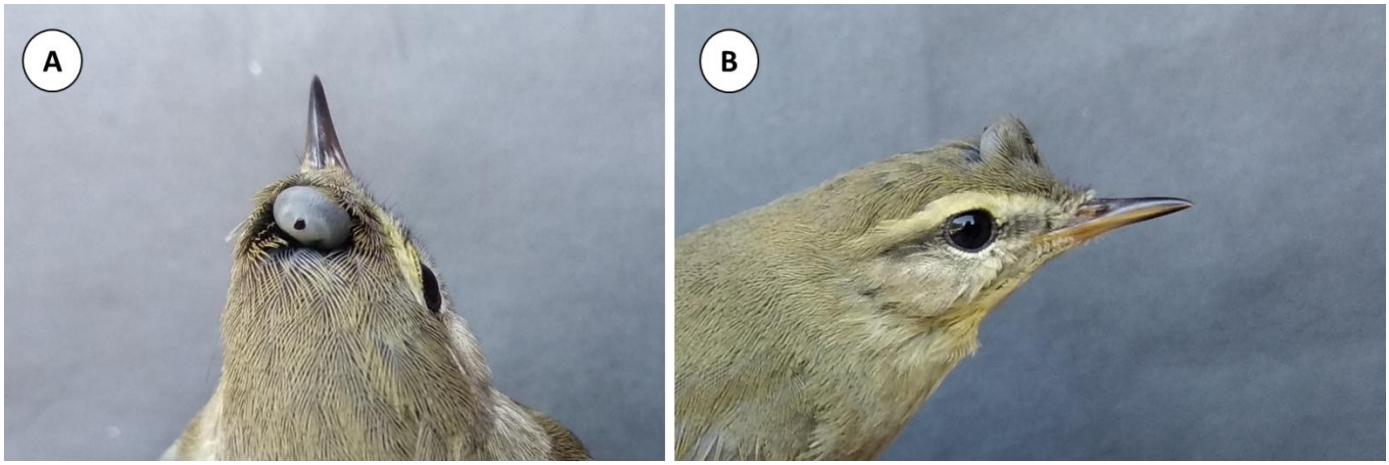

Figure 2. Willow Warbler, *Phylloscopus trochilus*, parasitized by a fully engorged nymph (*Hyalomma* sp.). **A.** Dorsal view, **B.** Lateral view.

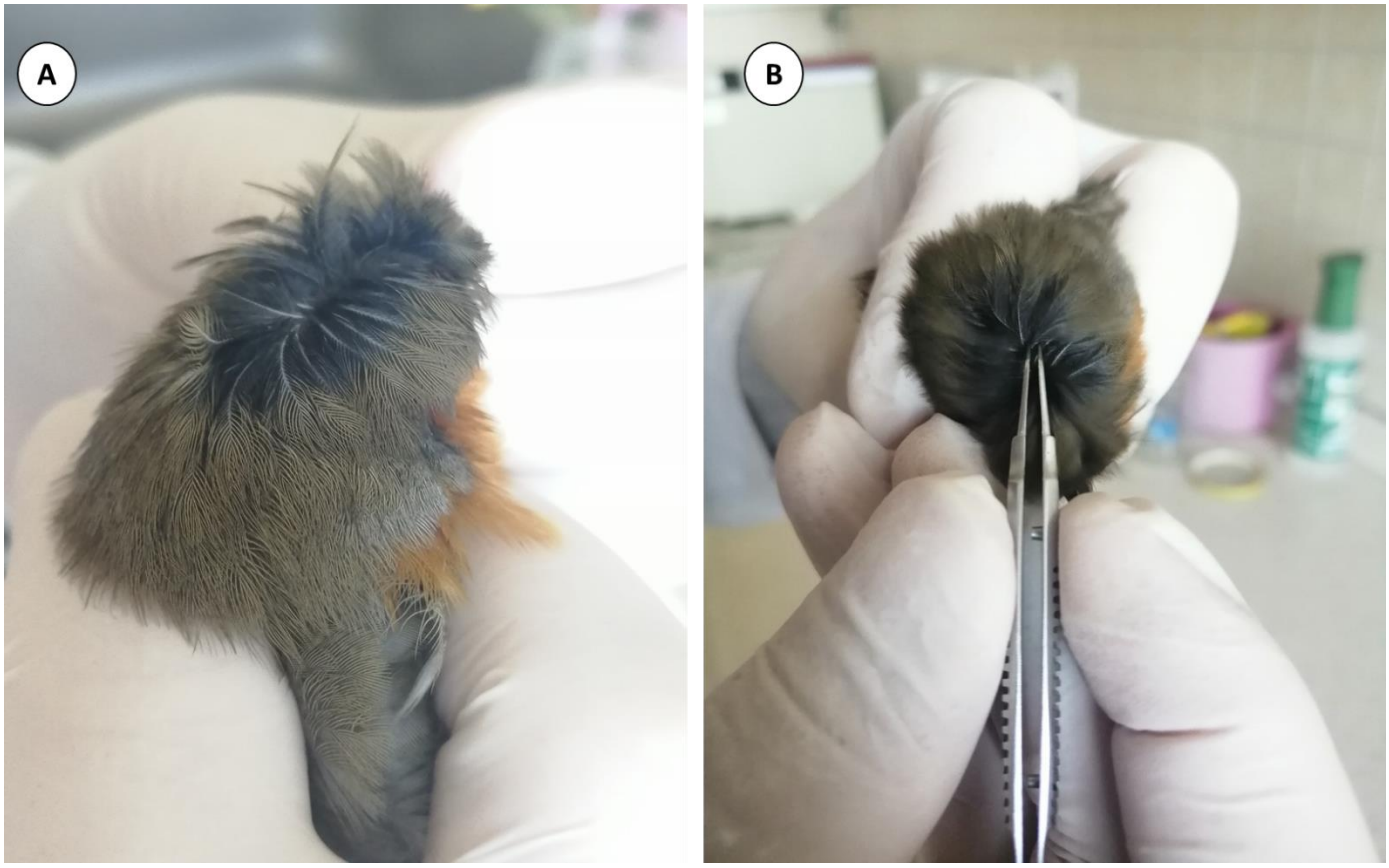

Figure 3. A European Robin, *Erithacus rubecula*. **A.** Examination of tick presence, **B.** Collection of immature ticks by a tweezer.

name. Alternatively, the sampling number recorded on the bird's ringing protocol form can be written on the label. If preferred an individual identical coding system can be used to shorten the process of writing. The ring number or a sampling number can be used which will connect a collected tick to the host species, morphometries of the host species, date of sampling and all other relevant data and information. Depending on the study, ticks collected from one bird can either be stored separately or all in one tube. The decided sampling protocol should be followed, and to avoid any contamination it is recommended to put each tick to separate vials. If there is a need to store the samples at -20°C or -80°C immediately after collection, which is usually not the case in ringing stations which do not have laboratory conditions, it is recommended to use liquid nitrogen tanks to store the samples until they will be transported to the laboratory (Wilkinson et al., 2014; Medlock et al., 2018).

Adult ticks can be easily identified using morphological characteristics, while the identification of immature ticks, especially those of the larvae, can be extremely difficult. The majority of ticks collected from birds are clean and require little or no extra work before placing them under the stereo-microscope. However, in some cases, dirt or host skin secretions can make the identification more difficult. In these cases, ticks should be dipped with a fine brush in alcohol.

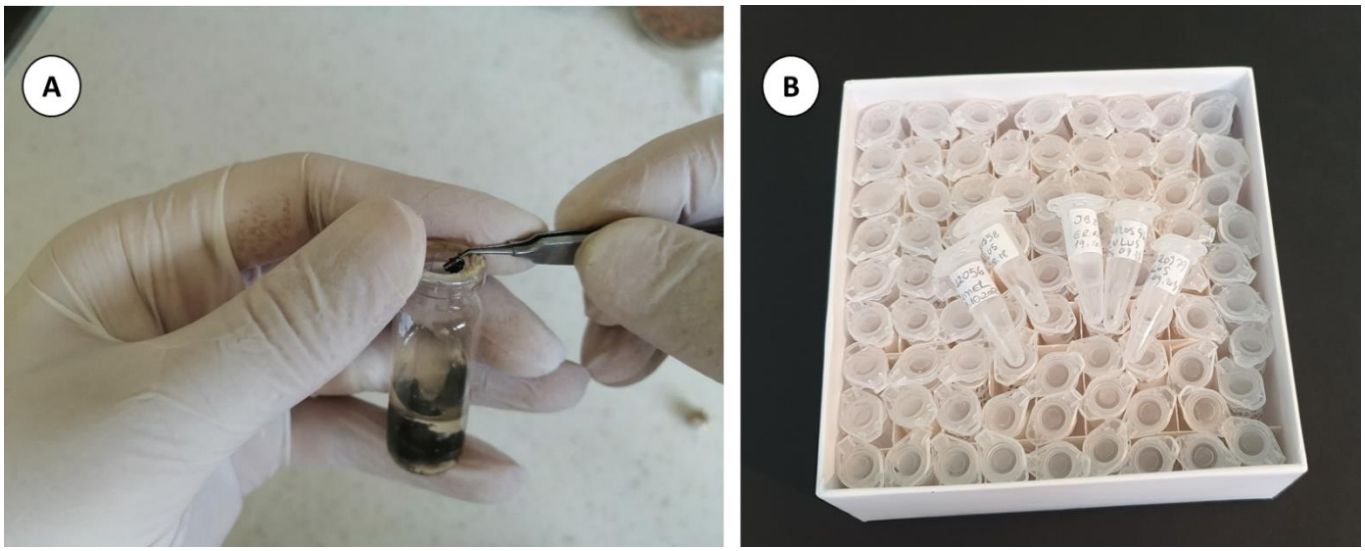

Figure 4. Storing of collected ticks. **A.** Ticks placed in 70% ethanol, **B.** Labelled tubes.

Host skin remains on the hypostome of a tick can be removed using steel tweezers. For the identification of larvae, in many cases, it might be necessary to clear and mount the ticks for their identification under the light microscope. Larval specimens should be cleared with lactic acid at 70°C for about 10 minutes. In case those larvae are engorged, they should be punctured and gently squeezed so as to remove much of the blood. Cleared larvae can be mounted in Hoyer's medium (200 g chloralhydrate, 30 g gum arabic, 20 ml glycerin, 50 ml distilled water). For the clearing and mounting process of larvae, following steps may alternatively be followed; (1)washing in distilled water, (2) clearing in 10% potassium hydroxide for 1-2 days, (3) washing in distilled water to remove the potassium hydroxide, (4) transferring to lactic acid for at least one hour to make them free from acid, (5) dehydrating in at least 10 minutes in 80%, 90% and absolute alcohol, each, (6) keeping in pure xylene or toluene for ca. 20 minutes, (7) sinking in cloves oil, preferably a day or longer, (8) mounting in Canada Balsam and drying on a hot plate or oven at 80°C.

Engorged immature ticks could be kept in well ventilated plastic tubes, usually at 25-27 °C and over 80% RH, until they molt to the following stage (Allan, 2013).Alternatively molecular tools such as Polymerase Chain Reaction (PCR) can be used for the identification of immature ticks (Black and Piesman, 1994; Karger et al., 2012).

For the collection of endophilic ticks from the bird nests, the nest material should be placed on a mesh over a Berlese-Tullgren funnel. The living immature ticks and also other arthropods within the nest material will move downwards in order to avoid the heat on the top of the examined material and drop into a bottle with 70% ethanol (Barton, 1995; Mumcuoglu et al., 2005; Kim et al., 2018).

Morphology based identification keys for ixodid and argasid ticks (adults and/or immatures) are available for Palearctic region (Filippova, 1977, 1997; Estrada-Peña et al., 2017); for Nearctic region (Clifford et al., 1961; Durden and Keirans, 1996); for Neotropical region (Martins et al., 2010; Nava et al., 2017); for Afrotropical region (Arthur, 1965; Horak et al., 2018); for Australian region (Roberts, 1970; Barker and Walker, 2014). For the immature ticks of *Rhipicephalus* spp. the taxonomic keys of Walker et al. (2000) and for *Hyalomma* spp. those of Apanaskevich and Horak (2008) could be used.

Conclusions

Ticks are known vectors of many pathogenic agents of medical and veterinary importance; therefore, they have always attracted the attention of biologists, veterinarians and public health workers. The emergence or re-emergence of many pathogenic agents transmitted by ticks infesting birds is also a major global concern, and a collaboration between ornithologists, tick taxonomists, and molecular biologists is of paramount importance. Collaborating with ringing stations gives a good opportunity to widen the scope of tick collection. Also makes the development of monitoring of ticks easier, cheaper and more efficient. Scientists working with ticks could contact local or regional ringing stations in order to add a tick sampling protocol within the ringing procedure without affecting the welfare of birds. Most of the studies do not refer to the infestation rates and focus mainly on the tick-borne diseases. It is recommended to set up a global tick surveillance reporting system to follow the number of examined birds, species of birds, number of ticks, and the ticks found on specific bird species and their density. To quickly relate vector born infections with proper hosts, a public database on tick and their hosts will direct people correctly and increase time efficiency.

Authors' contributions

Adem Keskin: Conceptualization, methodology, resources, visualization, writing - original draft, writing - review & editing. **Kiraz Erciyas-Yavuz:** Conceptualization, methodology, resources, visualization, writing - original draft, writing - review & editing. **Arif Cemal Özsemir:** Resources, visualization, writing - original draft. **Kosta Y. Mumcuoglu:** Methodology, supervision, writing - original draft, writing - review & editing.

Statement of ethics approval

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Conflict of interest

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

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RESEARCH ARTICLE

The Eldari tick *Ixodes eldaricus* (Acari: Ixodidae) in Israel: its occurrence, morphometric and biological characteristics

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ABSTRACT: An isolated population of the Eldari tick *Ixodes eldaricus* Dzhaparidze was studied in the southernmost part of the tick range (western surroundings of Jerusalem, Israel). Unfed adult and nymphal ticks were active from November through April. Ticks could be collected by flagging only from the grass just above the earth. A bimodal activity pattern was observed for adults with a decline in January characterized by the lowest air temperatures. Nymphal ticks had smaller size of their scutum as compared with specimens from the main part of the range. No mating adults were found during survey but when placed in a tube, males and females were immediately observed in the mating position. No tendency to attack humans or attach to them were registered in the field or in laboratory experiments. While having no apparent epidemiological significance, *I. eldaricus* deserves attention because of its possible role in epizootiology of rickettsial infections, which are common in the area of the survey.

Keywords: *Ixodes eldaricus*, *redikorzevi* group, season of tick activity, tick size and weight, mating, human affinity, epizootiology, Israel.

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INTRODUCTION

In the last decades, the interests of acarologists have been concentrated on about 20-25 tick species of clear medical or veterinary importance (Uspensky, 2006). Hundreds of other species have been favored with researcher's attention only occasionally, if at all. The Eldari tick, *Ixodes eldaricus* Dzhaparidze, 1950, is one of such scarcely studied species. The species was described based on a specimen of an adult female collected near Eldari village located in the Eldari valley (Georgia, then Georgian SSR of the USSR) (Dzhaparidze, 1950). Since its description, only a couple dozen papers have been published, mainly documenting findings of the species in different areas or on various hosts. Only fragmentary information on its biology and ecology can be gleaned from the published literature.

Ixodes eldaricus is the member of the subgenus *Ixodes* (s. str.). The species was considered closely connected with representatives of the *persulcatus* group (Filippova, 1974, 1977, 2008). Later the species was included together with *I. redikorzevi* Olenev, *I. occultus* Pomerantzev and *I. laguri* Olenev in a newly created *redikorzevi* group (Filippova, 2008).

The range of *I. eldaricus* includes the Crimea, the Caucasus (Georgia, Armenia, Azerbaijan, and Dagestan of Russia), Central Asian states (Turkmenistan, Tadzhikistan, Uzbekistan, southern parts of Kazakhstan and Kirgizstan), Iraq and Israel (Filippova, 1974, 1977; Kolonin, 1981). The tick inhabits mountain forests at 300 to 1,800 m above sea level (a.s.l.). Adults parasitize birds, while preadults parasitize birds as well as some small mammals (rodents and insectivores). Nymphs and adult ticks were found on spring migrating birds in Cyprus (Kaiser et al., 1974), Poland (Nowak-Chmura, 2012) and in Turkey (Keskin and Erciyas-Yavuz, 2019). The morphological description of all parasitic stages of *I. eldaricus* as well as the available data on its ecology and biology were summarized by N.A. Filippova (1974, 1977).

In Israel *I. eldaricus* was first collected from the rock partridge, *Alectoris graeca* Meisner (apparently, its eastern equivalent the Chukar partridge, *A. chukar* [J.E. Gray]), about 20 km south of Jerusalem, this finding being first attributed to a new species *Ixodes tatei* Arthur described by Arthur (1959, 1968) on the basis of findings in Iraq. Later *I. tatei* was synonymized with *I. eldaricus* (Filippova, 1974). Yeruham et al. (1995) collected all stages of *I. eldaricus* on the western foothills of Judea (30 km west of Jerusalem) by dragging and flagging. Larvae were also collected from 2 species of rodents, *Acomys cahirinus* (É. Geoffroy) and *Mus musculus* L.

The results of our survey of *I. eldaricus* including data on size and weight characteristics and biological patterns of this tick are presented below.

MATERIALS AND METHODS

The site of the survey is located in a hilly area of the Judean Mountains in the western part of Judea (20 km west from Jerusalem). The area is covered with natural Mediterranean forests as well as with planted pine trees. Southwestern (with a creek drying in the summer) and northeastern slopes of a valley along the road Abu-Gosh - Nataf at 550 to 600 m a.s.l. (31°82'N, 35°09'E) were under observation. Ticks were collected by flagging (a white flannel flag by 1x1 m) during October-April 2006/2007. The collections were carried out twice per month on both

slopes, along roads, which are rarely used. Two collectors worked at each site for 45 to 60 min. The tick abundance was estimated as the number of ticks collected by 1 person during 1 hour. During a total of 45 hours of collection, over 200 ticks (adults and nymphs) were collected. The average daily and monthly temperatures in Jerusalem area, multiannual and for the period of the survey, were taken from the archive of the Central Bureau of Statistics (Israel) (http://www.cbs.gov.il). Twice during that period goats from a farm nearby were inspected. An attempt was also undertaken to collect ticks in the area of Yeruham's survey (1995); sporadic attempts of collecting ticks in different areas of Jerusalem and its suburbs were made in February-March 2008 and in summer months (May to September), 2011.

A sample of ticks from our collections (in total 20 males, 25 females, and 20 nymphs) were measured under stereomicroscope with ocular micrometer. Ticks (in total 46 males, 69 females, and 36 nymphs) were also weighed on an electronic scale.

Observations on some features of tick behavior were carried out using ticks collected in the field. Adults of different size ("big" and "small" according visual estimation) in various numbers and combinations were put into glass tubes immediately after collecting; the time before mating and the influence of tick size on mating were noted. A total of 43 males and 76 females collected in February-March were used in these tests. Tick affinity for attacking and biting humans was checked by regular cross-examinations of collectors' clothes and in special tests made in the laboratory. For this purpose, a number of unfed females were placed after collection into specially-equipped glass tubes (Uspensky, 1967) where a gradient of humidity (65-95% RH) was created along the length of each tube (Shashina and Ioffe, 1980). The tests were carried out at the next day after tick collection. The ticks were individually put on the researcher's arm and were observed for up to 1 hour. The temperature in the laboratory was 23-25ºC. A total of 15 females collected in October-November and of 20 females collected in March were used in the tests.

RESULTS

Occurrence

First ticks were collected in November and the tick activity was observed till the end of April. Adult ticks were regularly collected during the entire period of observation. Single nymphs were sporadically collected during the same period with an obvious increase in March. Not a single larval specimen was found. Ticks were collected only from the grass slightly above the ground and were never found on higher vegetation. When on the flag, they did not demonstrate any activity, passively remaining in one spot on the flag. The results of tick collections on the southwestern slope are presented on Fig. 1. The adult tick activity was higher in the beginning of the activity season (November-December) and in its second part (February-March) with a strong decline in January. The numbers of ticks collected on the northeastern slope was much smaller and those data are omitted.

Mean daily air temperatures in November-December, 2006 were lower than the mean daily multiannual temperatures of those months, while in January-April, 2007 mean daily temperatures were higher than the mean multiannual ones (Fig. 2). January was characterized by a strong decline of maximal and minimal daily temperatures.

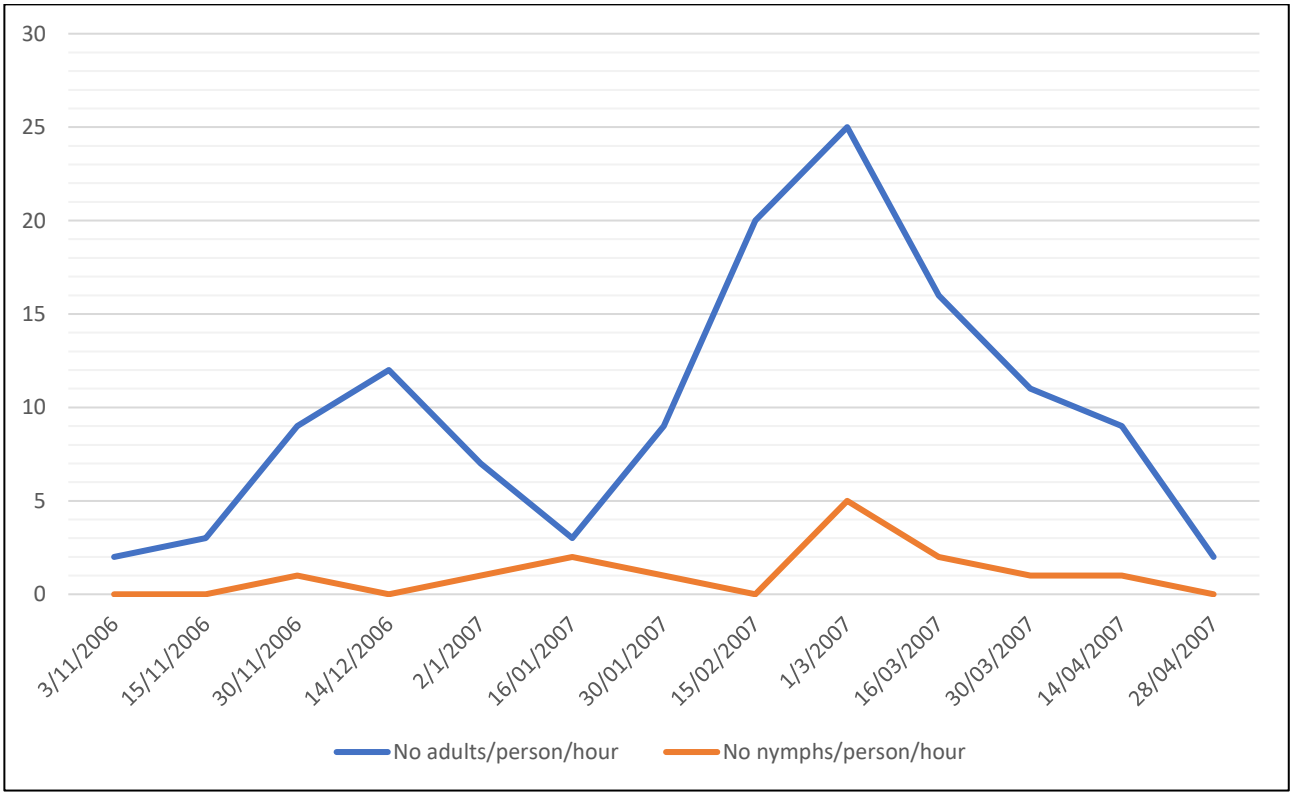

Figure 1. No of ticks collected in the survey area (vertical axis – No of ticks).

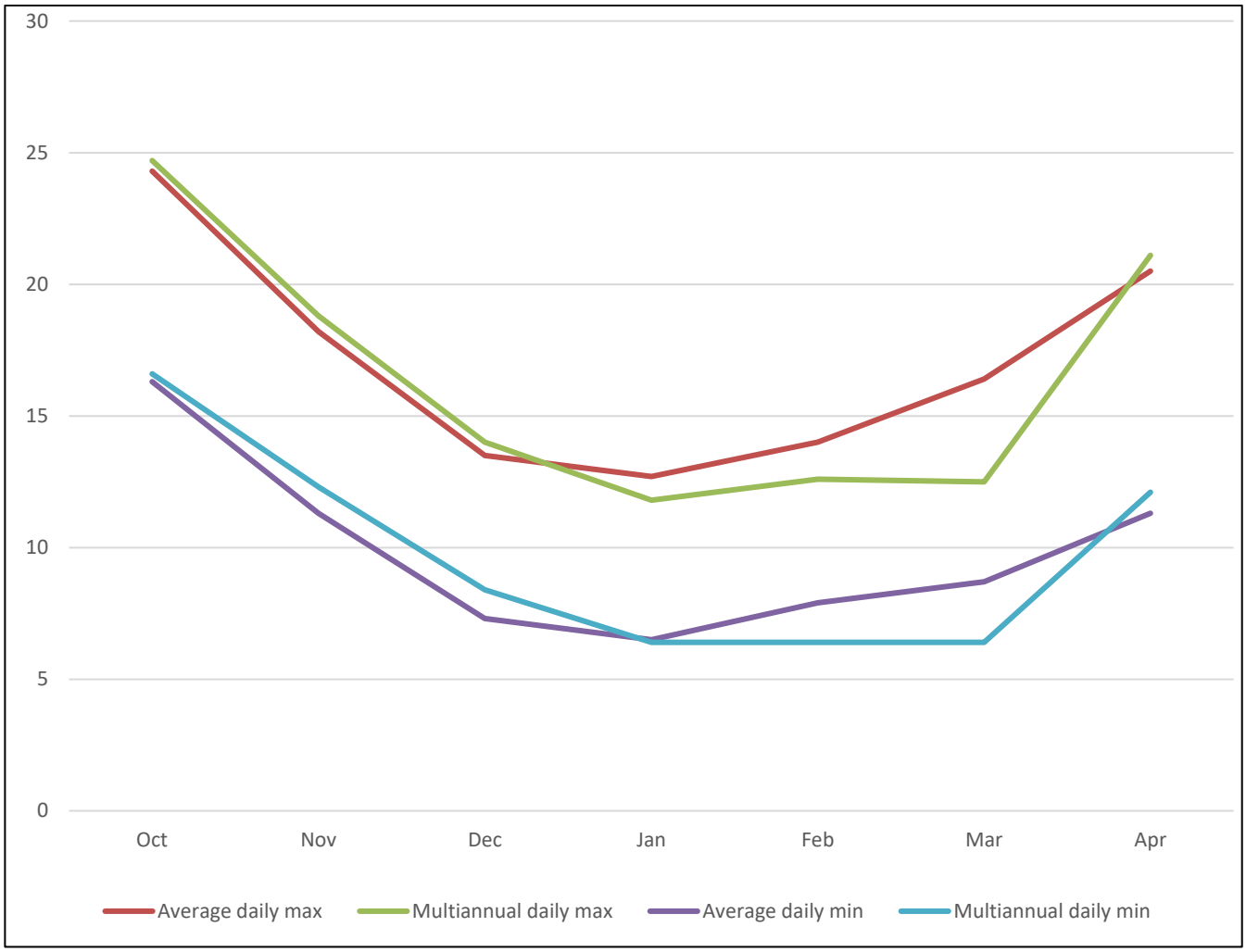

Figure 2. Maximal and minimal average daily temperatures: in the season 2006/2007 and multiannual (vertical axis – temperature in ºC).

Table 1. Size and weight characteristics of unfed nymphal and adult *I. eldaricus* [Mean ± SD, (range)].

Characteristics	Nymphs	Adults	
		Males	Females
Scutum (conscutum for males), mm	0.527 ± 0.051 (0.439 – 0.610)	1.84 ± 0.10 (1.66 – 2.00)	1.2 ± 0.12 (0.93 – 1.37)
width	0.451 ± 0.058 (0.366 – 0.561)	0.98 ± 0.07 (0.87 – 1.10)	0.91 ± 0.07 (0.78 – 1.03)
Alloscutum, mm length	0.992 ± 0.065 (0.875 – 1.078)		2.17 ± 0.11 (2.00 – 2.39)
Width	0.585 ± 0.058 (0.488 – 0.648)		1.35 ± 0.09 (1.19 – 1.51)
Weight, mg	0.12 ± 0.01 (0.085 – 0.15)	0.79 ± 0.11 (0.45 - 1.0)	1.18 ± 0.27 (0.6 - 1.9)

When goats from the farm located near-by that had been pastured over the sites of survey were examined, we found no *Ixodes* ticks but only a small number of ticks of the genus *Haemaphysalis*.

An attempt to collect ticks at the site of previous collections (Yeruham et al., 1995) was unsuccessful: not a single specimen was found. Additionally, one male of *I. eldaricus* was collected by flagging grass vegetation in the southern part of Jerusalem, in a woody ravine dividing two residential areas in March, 2008. No ticks were found in summer months.

Size and weight characteristics

The measurements of the scutal/conscutal length and width for males, females and nymphs and of the alloscutal length and width for females and nymphs as well as the weights of ticks from these groups are presented in Table 1.

Biological patterns

No adults in the mating position were found during tick collection. However, when collected ticks of different sex were put together in the same tubes, it took 1 to 3 min for ticks to be in the mating position. Large females were preferable for males and large males had advantage over small males. In any case, mating took place regardless of the male size. Interestingly, these patterns of behavior were consistently observed in all of our tests.

Not a single tick was found on the collector's clothes during tick collection. When unfed females were put on a human arm, no cases of tick attachment were observed (Table 2). More than 80% of ticks left the arm after 30 min of observation and more than 90% after 45 min.

Table 2. Affinity for attacking humans in unfed *I. eldaricus* females.

Ticks		**No. ticks left on the arm, min**				**No. ticks kept on the arm after 1 h**	**No. ticks attached to the arm**
Collected in	No.	<15	16-30	31-45	46-60		
October-November	15	4	8	2	0	1	0
March	20	8	10	1	1	0	0

DISCUSSION

Although *I. eldaricus* inhabits xerophilous mountain forests and bush, the tick avoids both very high and very low temperatures and prefers habitats, characterized by adequate humidity. This is indicated by the differences in the seasons of activity of the tick (spring and autumn months in the northern part of the range (Filippova, 1977) and winter months in our observations and in those by Yeruham et al. (1995), and by its preferential occurrence in the areas characterized by higher humidity and lower sun irradiation in our and Yeruham's observations. A bimodal activity pattern with a strong decline of activity in January observed in our survey is also common to *I. ricinus* near the southern border of its range (Daniel et al., 2015; Aydin et al., 2020). Our data allow to estimate the average daily maximal air temperatures in the range of 13-20°C as optimal for activity of adult *I. eldaricus*. The minimal daily temperatures appear less essential since their values in December and February were close to those in January (Fig. 2) and did not suppress high tick activity. It is unclear whether the differences in temperatures of the 2006/2007 season from multiannual ones (lower in October-December and higher in February-March) influenced the tick activity pattern. Our observation on tick abundance dynamics during the season of their activity is a first attempt of such kind. We have no ready explanation for the absence of larval ticks in our collections as compared with data by Yeruham et al. (1995).

The habitats of *I. eldaricus* usually look as "spots" among xerophilic vegetation typical for the entire range of this species. Tick location in the lowest level of the vegetation and their low activity determine various degrees of isolation of *I. eldaricus* populations from each other with possible connection provided only by the bird hosts. Our lack of success in finding ticks at the site of Yeruham's collections may be explained by a drastic decrease in soil humidity following the planting of eucalyptus trees in the area. In the Crimea, this species has been classified as "disappearing" (Nebogatkin, 1998) because of anthropogenic destruction of its habitats and reduction of host populations in the 1990s. Gradual warming of the Earth's temperature in the past decades may also be an unfavorable factor for *I. eldaricus* populations.

Since *I. eldaricus* is characterized by low abundance, low activity and specificity in locations and hosts (and is not of the primary interest of researchers), its geographic range is insufficiently described. Main hosts of *I. eldaricus* in all parasitic stages are ground-foraging passerine birds, many of them with a limited distance of seasonal migrations. Findings of specimens of this tick on migrating birds in Cyprus (Kaiser et al., 1974) and Turkey (Keskin and Erciyas-Yavuz, 2019) were thought to be the result of bird infestation in the same or adjacent countries. It was also suggested that this species should be present in Iran (Filippova et al., 1976). Most probably, isolated populations of *I. eldaricus* can be found in Lebanon and western part of Syria. Long-distance introduction of specimens of this species is extremely rare; only one case of such kind has been documented to date (Nowak-Chmura, 2012).

Ixodes eldaricus was first considered closely connected with the species from the *persulcatus* group (Filippova, 1974, 1977) but later it was included in a newly created *redikorzevi* group (Filippova, 2008). It may be informative to compare our data with the corresponding published data on both of these groups.

The scutum of *I. eldaricus* nymphs from our collections is a little shorter (but statistically significantly, according to the Student's *t*-criterion = 4.58) than that of nymphal *I. eldaricus* from other parts of the range (Filippova, 1974, 1977). It might be explained by the fact that the area of our survey is located in the southernmost part of the tick range where the conditions are less favorable than in the main part of its range. At the same time, it is comparable with the data for *I. redikorzevi* and *I. occultus* but less than that of the ticks from the *persulcatus* group (Filippova, 1977). The weight of *I. eldaricus* nymphs is a little less than that of nymphal *I. persulcatus* and *I. ricinus*, while the weight *I. eldaricus* females is about half that of the two species mentioned above (Uspensky et al., 1999). It means that nymphs of *I. eldaricus* engorge less blood than the ticks of the *persulcatus* group. Using the data on feeding of adult *I. redikorzevi* obtained by Tiflova (1974), we

can assume that the mean weight of engorged *I. eldaricus* females could not exceed 100 mg.

No copulating pairs of *I. eldaricus* adults were found during tick collection which strongly differs from *I. persulcatus* or *I. ricinus* whose adults were regularly found in the mating position (Ioffe-Uspensky and Uspensky, 2017). However, field-collected males and females of *I. eldaricus* mated immediately after being placed together in the same tube, similarly to *I. persulcatus* specimens. Interestingly, in our previous experiments with a laboratory colony of *I. persulcatus* (Uspensky and Repkina, 1978), virgin adults could be together in the tube for up to 31 days making no attempt to mate. It is possible that pheromone regulation is fully manifested only in the field populations of adult *Ixodes* ticks and is suppressed in the laboratory conditions. The absence of copulating *I. eldaricus* adults in the field puts question on pheromone regulation in this species as compared with *I. persulcatus* and *I. ricinus* ticks where such regulation does exist (Uspensky and Yemel'yanova, 1980; Háiková and Leahy, 1982).

Adult *I. eldaricus* did not show any aggressiveness toward humans while *I. persulcatus* is a very aggressive species (Uspensky, 1993, 2016). This is in agreement with Filippova's observations (1974, 1977) that *I. eldaricus* was not found attacking humans in nature. A tick species which have no epidemiological significance might, however, have certain significance in epizootiology of known and unknown infections. For example, such species as *I. arboricola*, another poorly-studies species, only recently was found to participate in circulating several rickettsia species among bird hosts (Špitalská et al., 2011). Considering that *I. eldaricus* can be found in areas where *Rickettsia conorii israelensis* and other rickettsial agents are spread (Guberman et al., 1996; Mumcuoglu et al., 2002; Rose et al., 2017), the necessity of studying the role of this species in epizootiology of these pathogens is important.

It would be informative to test Israeli *I. eldaricus* for *Borrelia burgdorferi* s.l., especially in view of the following considerations:

(i) The range of *I. ricinus*, one of the main vectors of that pathogen, covers the territory of the Levant from Turkey (Bursali et al., 2012) to the northern part of Israel (Erster et al., 2013) (although there is no data from Lebanon and the western part of Syria, it would be reasonable to assume that this tick populates the forested areas of these countries, especially the mountain forests). *Borrelia burgdorferi* s.l. was isolated from *I. ricinus* in Turkey (Güner et al., 2003; Polat et al., 2017) and a systematic review of the available data (Önal et al., 2019) indicates that Lyme borreliosis is a major health concern in the country;

(ii) Ground-foraging passerine birds are important hosts for *I. ricinus* and dominant hosts for *I. eldaricus*, a number of species being common for both tick species (Filippova, 1977). These bird species are not only good tick carriers, but also competent reservoirs of several genospecies of *B. burgdorferi* (Comstedt et al., 2006; Taragel'ová et al., 2008; Norte et al., 2012);

(iii) The routes of seasonal migrations of many passerine birds between Europe and Eastern Africa lie through Israel and Turkey (Inci et al., 2016) with stopover sites in both countries (Frumkin et al., 1995; Inci et al., 2016), which provides favorable conditions for circulation of ticks and tick-borne pathogens throughout the Levant.

When these facts are considered together, it appears rather likely that *B. burgdorferi* circulates between birds and ticks in forested areas of Israel, and that *I. eldaricus* is one of the tick species mediating this process.

Statement of ethics approval

Not applicable.

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Conflict of interest

There is no potential conflict of interest.

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RESEARCH ARTICLE

Species composition of hard ticks (Acari: Ixodidae) on domestic animals and their public health importance in Tamil Nadu, South India

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ABSTRACT: This study was carried out in Madurai district, Tamil Nadu State, South India. Ticks were collected from cows, dogs, goats, cats and fowls. The overall percentage of tick infestation in these domestic animals was 21.90%. The following ticks were identified: *Amblyomma integrum, Haemaphysalis bispinosa*, *Haemaphysalis paraturturis*, *Haemaphysalis turturis*, *Haemaphysalis intermedia*, *Haemaphysalis spinigera*, *Hyalomma anatolicum*, *Hyalomma brevipunctata*, *Hyalomma kumari*, *Rhipicephalus turanicus*, *Rhipicephalus haemaphysaloides* and *Rhipicephalus sanguineus.* The predominant species recorded from these areas is *R. sanguineus* (27.03%) followed by both *R* (*B.*) *microplus* (24.12%) and *R.* (*B.*) *decoloratus* (18.82%). The maximum tick infestation rate was recorded in animals from rural areas (25.67%), followed by semi-urban (21.66%) and urban (16.05%) areas. This study proved the predominance of hard ticks as parasites on domestic animals and will help the public health personnel to understand the ground-level situation and to take up necessary control measures to prevent tick-borne diseases.

Keywords: Ticks, domestic animals, Ixodidae, prevalence.

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INTRODUCTION

Hard ticks (Acari: Ixodidae) are involved in the transmission of a variety of disease pathogens of public health and veterinary importance (Arthur, 1962; Estrada-Pena and Jongejan, 1999; Parola and Raoult, 2001; Barandika et al., 2007; Brites-Neto et al., 2015; Liyannaarachchi et al., 2015; Tonetti et al., 2020). Today, the order Ixodida includes 970 species of ticks known all over the world which are included in four families, being three extant Ixodidae (750 spp.), Argasidae (218 spp.), one Nuttalliellidae and one extinct Deinocrotonidae (Guglielmone et al., 2015; Dantas-Torres et al., 2019). In India, domestic animals are often infested heavily with multi-species of ticks transmitting different diseases such as theileriosis, babesiosis, and anaplasmosis (Ghosh and Nagar, 2014). Tick studies gained much significance after the Shimoga district of Karnataka state, reported Kyasanur Forest Disease (KFD) transmitted by *Haemaphysalis* spp. (Pattnaik, 2006). Crimean-Congo hemorrhagic fever (CCHFV) virus infection in domestic animals and humans were reported from different parts of the country (Shanmugan et al., 1976). So far in Madurai district, no tick surveillance was undertaken and no data is available about the distribution pattern of the ticks. Hence this study was undertaken to study the available tick species and to know about the prevalence of different vector species in Madurai district.

MATERIALS AND METHODS

Madurai district situated in the Tamil Nadu state of India is one of the 38 districts in the Tamil Nadu state. The latitude of Madurai, Tamil Nadu, India is 9.9533° N and the longitude is 78.0195° E. The geographical area of this district is 147.97 km^2. The total population as per the 2011 census is 1,470,755. The average annual minimum temperature in Madurai is 23.9 °C, the average maximum is 34.5 °C, and the annual rainfall is 869.4 mm (34.23 inch). The study area of Madurai was grouped into three regions viz. urban, semi-urban, and rural environmentals (Fig. 1). In each habitat, 100 households were selected randomly. This study incorporated different household animals like cows, dogs, goats, cats and fowls. Ticks were collected with fine-tipped tweezers and kept separately for identification in sample vial containing 70% ethanol, location, host, and date of collection was noted. Ticks were identified using the available tick identification keys (Sharif, 1928; Geevarghese and Dhanda, 1987; Walker et al., 2003; Geevargheese and Mishra, 2011). Immature ticks were mounted with Hoyer's medium (Prakasan and Ramani, 2007). All collected specimens were deposited in Mosquito/Ectoparasite Museum, Entomology Laboratory of ICMR-Vector Control Research Centre Field Station, Tamil Nadu, India. The tick index and the tick infestation rate were calculated. The data analysis was performed using SPSS Ver. 15 (Statistics Package for Social Sciences).

RESULTS

This study showed the presence of ticks on 1,224 household animals cows (417), dogs (153), goats (465), cats (19), and fowl (170) belonged to 14 species and 5 genera. The following ticks wereidentified: *Amblyomma integrum* Karsch, 1879, *Haemaphysalis bispinosa*, Newmann, 1897, *Haemaphysalis paraturturis* Hoogstraal, Trapido and Rebello, 1963, *Haemaphysalis turturis* Nuttall and

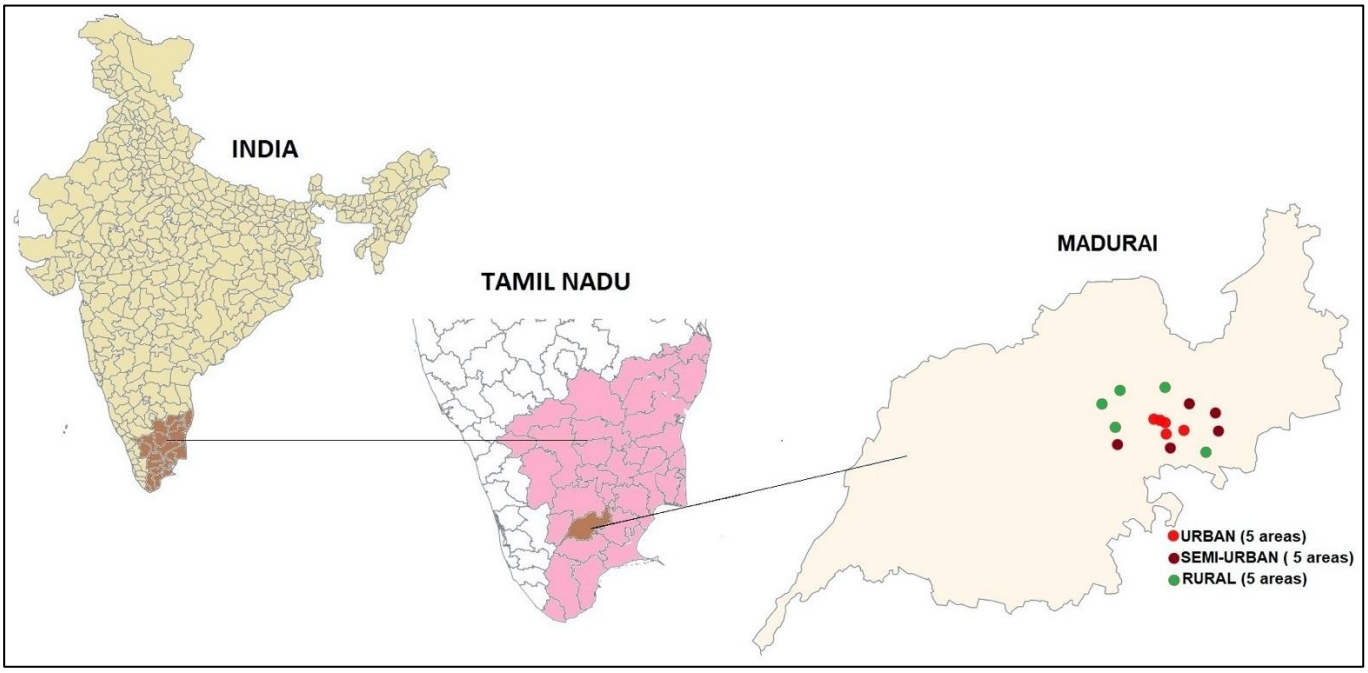

Figure 1. Localities where the field work was carried out in Madurai district.

Warburton, 1915, *Haemaphysalis intermedia* Warburton and Nuttall, 1909, *Haemaphysalis spinigera* Neumann, 1897, *Hyalomma anatolicum* (Koch, 1844), *Hyalomma brevipunctata* Sharif, 1928, *Hyalomma kumari* Sharif, 1928, *Rhipicephalus* (*Boophilus*) *annulatus* (Say, 1821), *Rhipicephalus* (*B.*) *decoloratus* (Koch, 1844), *Rhipicephalus* (*B.*) *microplus* (Canestrini, 1887), *Rhipicephalus turanicus* Pomerantzev, 1940, *Rhipicephalus haemaphysaloides* Supino, 1897, and *Rhipicephalus sanguineus* complex (Latrielle 1806) (Table 1). A list of 15 tick species collected in this study and the detailed gender and life stage is shown in Table 1.

Prevalence and infestation details of tick species in domestic animals is furnished in Table 1 and 2. Among the three localities, the maximum collection was recorded from semi-urban areas. The total tick infestation rate was calculated to be 21.90% and the tick index was 0.922. In the rural areas 13 species of ticks were found, followed by 11 species of ticks recorded from semi-urban areas and eight from urban areas. The rural habitat showed a maximum number of tick species. The predominant species recorded from these areas was *R. sanguineus* complex (27.03%), followed by both *R.* (*B.*) *microplus* and *R.* (*B.*) *decoloratus* (24.12% and 18.82%), respectively. The maximum number of ticks were collected from cows (41.43% of the ticks), followed by dogs (18.02 %), goats (36.92%), cats (1.59%) and fowls (2.03%). Tick abundance rate concerning different host animals was 27.33% for cows, 22.88% for dogs, 19.35% for goats, 36.84% for cats, and 12.94% for fowl (Table 2). Ticks were collected mostly from ears followed by neck and udder of the animals. A list of 10 medically important tick vectors collected in this study is shown in Table 3.

There was a significant difference in the distribution of ticks among rural, semi-urban, and urban localities (F-5.465, df-2, $p<0.05$). Again there was a significant difference in the distribution of ticks among the five host animal groups (F-4.938, df-4, $p<0.05$). Finally, cross-analysis of three localities versus 5 host (15 species of ticks) showed a significant difference among the tick positivity (F-3.287, df-14, $p<0.05$).

DISCUSSION

The first major contribution to Indian tick fauna was by Sharif (1928), who reported 45 species of ticks preserved in the Zoological Survey of India (Indian Museum in Calcutta. Sen (1938) prepared a check-list for 50 species of Ixodid ticks found on the domestic stock. A check-list of different tick species on various vertebrate hosts and from many areas of the country was prepared by the National Institute of Virology in Pune (Geevarghese et al., 1997; Geevargheese and Mishra, 2011). In India, so far 109 tick species were reported of which 88 belong to the family Ixodidae (Geevarghese et al., 1997; Ghosh et al., 2007). Tick faunal studies from the eastern Himalayas recorded 14 different species of ixodid ticks belonging to seven genera with an abundant collection of *Amblyomma* spp. and *R.* (*B.*) *microplus* (Varma and Mahadevan, 1970). In Jammu and Kashmir 16 different species of ixodid ticks belonging to seven genera were recorded (Kaul et al., 1990). Ixodid ticks belonging to seven genera and 17 species were collected from North-East Frontier Agency, India (Dhanda and Ramachandrarao, 1964).

In Haryana, six different tick species from three genera of hard ticks were collected (Chhilar et al., 2014). A study conducted in Karnataka reported hard ticks infesting sheep and goats (Jagannath and Lokesh, 1988; Saxena, 1997). Kumar et al. (2002) reported the presence of hard ticks in Tamil Nadu. Similarly in Kerala Prakasan and Ramani (2003) reported hard ticks infestation in humans. The presence of hard ticks in different domestic animals was already reported from many states like Karnataka, Tamil Nadu and Assam (Jagannah et al., 1979; Latha et al., 2004; Miranpuri and Singh, 1978). Saxana et al. (1984) reported eight different species of ticks, and Kumar et al.

Table 1. Prevalence of tick species in domestic animals in Madurai, Tamil Nadu, India.

Family	Genus	Species	Nymph	%	Male	%	Female	%	Total	%
Ixodidae	*Amblyomma*	*Amblyomma integrum*	3	0.27	1	0.09	10	0.88	14	1.24
	Haemaphysalis	*Haemaphysalis bispinosa*	8	0.71	14	1.24	75	6.63	97	8.57
		Haemaphysalis paraturturis	0	0.00	0	0.00	9	0.80	9	0.80
		Haemaphysalis turturis	8	0.71	2	0.18	21	1.86	31	2.74
		Haemaphysalis intermedia	7	0.62	12	1.06	34	3.00	53	4.68
		Haemaphysalis spinigera	0	0.00	2	0.18	14	1.24	16	1.41
	Hyalomma	*Hyalomma anatolicum*	0	0.00	0	0.00	12	1.06	12	1.06
		Hyalomma brevipunctata	2	0.18	0	0.00	9	0.80	11	0.97
		Hyalomma kumari	3	0.27	9	0.80	20	1.77	32	2.83
	Rhipicephalus	*Rhipicephalus* (*B.*) *annulatus*	3	0.27	0	0.00	14	1.24	17	1.50
		Rhipicephalus (*B.*) *decoloratus*	4	0.35	42	3.71	167	14.75	213	18.82
		Rhipicephalus (*B.*) *microplus*	1	0.09	84	7.42	188	16.61	273	24.12
		Rhipicephalus turanicus	2	0.18	11	0.97	26	2.30	39	3.45
		Rhipicephalus haemaphysaloides	0	0.00	2	0.18	7	0.62	9	0.80
		Rhipicephalus sanguineus	17	1.50	116	10.25	173	15.28	306	27.03
		Total	58	5.12	295	26.06	779	68.82	1132	100

Table 2. Tick infestation rate and tick index in study areas.

Host	Total host examined	Host infested	Total ticks collected	Infestation (%)	Tick index
Cow	417	114	469	27.34	1.12
Dog	153	35	204	22.88	1.33
Goat	465	90	418	19.35	0.90
Cat	19	7	18	36.84	0.95
Fowl	170	22	23	12.94	0.14
Total	1,224	268	1,132	21.90	0.92

Table 3. List of medically important tick vectors collected in this study.

No	Vector	Disease	Parasite/pathogens	R
1	*Amblyomma integrum*	Otoacariasis	Otalgia	R1
2	*Haemaphysalis intermedia*	Ganjam virus	Nairobi sheep disease	R3
3	*Haemaphysalis spinigera*	Kyasanur Forest disease	Group B Toganvirus (Flaviviridae)	R2
4	*Haemaphysalis turturis*	Kyasanur Forest disease	KFD virus	R2
5	*Hyalomma anatolicum*	Crimean-Congo haemorragic fever	*Babesia equi*	R2
6	*Rhipicephalus* (*B.*) *annulatus*	Babesiosis	*Babesia* sp.	R2
7	*Rhipicephalus* (*B.*) *decoloratus*	Indian tick typhus	*Rickettsia conorii*	R2
8	*Rhipicephalus* (*B.*) *microplus*	Babesiosis	*Babesia bigemina*, *B. ovis*	R2
9	*Rhipicephalus sanguineus*	Indian tick typhus, ehrlichiosis	*Rickettsia conorii*, *Ehrlichia canis*, *E. equi*	R2
10	*Rhipicephalus turanicus*	Rickettsial disease	*Coxiella, Rickettsia*	R4

R-References: R1-Bandaranayaka et al. (2016), R2-Ghosh and Nagar (2014), R3-Geevarghese and Mishra (2011), R4-Chochlakis et al. (2014).

(2014) reported 12 species of ticks on different domestic animals in Nilgiris hills situated in Tamil Nadu. A total of 14 species of ticks belonging to 5 genera infesting domestic animals in Villupuram district, Tamil Nadu were recorded Shobana et al. (2013). This study showed that more favourable conditions prevail in Madurai for the propagation of haematophagous ticks with richness in vegetation and animal fauna with special reference to rural areas. Similarly to the observations of Shobana et al. (2013) also in this study cats had a minimum number of ticks.

A study about the tick fauna in the Shimoga district of Karnataka showed the presence of *H. spinigera* on dogs which facilitate the maintenance of the Kyasanur Forest disease (KFD) virus (Kumar et al., 2008). In Shimla hills species like *Hyalomma* spp., *R. sanguineus complex*, *R. haemaphysaloides*, *Haemaphysalis* spp. and *Ixodes* spp. with their role in disease transmission (Mehta, 1937). The presence of *Hyalomma* species in the region confirms the presence of the CCHF virus in Gujarat (Gandhi et al., 2011). A large number of the species infesting the different livestock were recorded as vectors of different pathogens (Liyannaarachchi et al., 2015; Tonetti et al., 2020). Tick-borne diseases like KFD and CCHF are of public health importance and the KFD virus was isolated from tickssuch as *H. spinigera, H. turturis*, and *H. bispinosa* in India. This present study showed the prevalence of the different species of ticks and the pattern of infestation on different domestic animal hosts namely cows, goats, dogs, cats, and fowl. In this study we have also observed the presence of 10 species tick vectors and the disease they cause as shown in Table 2.

This study showed for the first time the species of ticks existing on livestock in the region of Madurai district. Further studies are required to understand the epidemiology of those ticks, their vectorial potential for pathogenic microorganisms as well as the seroprevalence of tick-borne diseases in the human population. Tick control methods are to be adopted to keep the tick abundance in check at regular intervals to prevent the spread of tick-borne diseases.

Authors' contributions

Krishnamoorthi Ranganathan: Collection of the specimens, processing of the specimens, identification and preservation. **Govindarajan Renu:** Collection of the specimens, processing of the specimens, identification, preservation, review and editing. **Elango Ayyanar:** Identification, verification, data curation. **Rajamannar Veeramanoharan:** Data analysis, visualization, software programming. **Philip Samuel Paulraj:** Conceptualization, supervision and project administration.

Statement of ethics approval

This study was approved by the Institutional Animal Ethics Committee (IAEC) of ICMT-Vector Control Research Centre, Puducherry.

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Conflict of interest

None of declare.

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RESEARCH ARTICLE

A faunistic survey of house dust mites of Kolkata, West Bengal, India

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ABSTRACT: House dust mites play an important role in causing various allergic disorders. Many factors like temperature, humidity as well as different microclimatic conditions may influence mite growth. The aim of this study was to analyse the mite fauna of Kolkata, West Bengal, India. House dust was collected from 20 selected houses located in and around Kolkata from January 2017 to December 2017. House dust samples were processed following the flotation technique and house dust mites were isolated from all the samples surveyed. A total of 51 species belonging to 34 genera and 17 families were isolated from positive samples. *Dermatophagoides pteronyssinus*, *Blomia tropicalis* and *Cheyletus malaccensis* were present in all positive samples. Most abundant mite in house dust was *Dermatophagoides pteronyssinus*, constitute 47% of the mites collected from dust samples. *Amblyseius longispinosus* was first time reported from Indian house dust.

Keywords: *Dermatophagoides pteronyssinus, D. farinae, Blomia tropicalis, Glycycometus geniculatus*, Acari.
Zoobank: http://zoobank.org/105512C3-6D37-47FD-ABAD-CC25820E41FC

INTRODUCTION

Mites are very diverse and wide spread groups of animals and cosmopolitan in nature. Schauff (2000) estimated more than 48,200 mite species present globally having various feeding habits such as plant feeders, fungivorous, coprophagous, saprophagous, carnivorous etc. while many other feeding habits are still unknown. Many of mite species are free living but there are some which parasitize plants and animal, and also act as reservoirs and vectors of serious pathogens causing rickettsial pox, protozoal, bacterial, spirochaete and viral diseases to livestock and human beings. House dust mites have earned a worldwide interest among acarologists and medical entomologists for their intricate association with human beings by playing a significant role in public health (Smith, 1983; Podder et al., 2006, 2010). Since house dust mites (Acarina: Pyroglyphidae) are known to be the cause of allergic diseases (Voorhorst et al., 1964), many surveys on their diversity and distribution have been carried out in the northern and southern part of India. In India, House dust mite survey was conducted more than 25 years ago and *Dermatophagoides pteronyssinus* was identified as the most common and abundant species (Rao et al., 1975; Tripathi et al., 1983; Valandiker and ChannaBasavanna, 1992; Lakshmi and Haq, 1999). Abundance of species is a dynamic process and depends upon environmental factors (Mariana et al., 2000). This was established when Chaudhury et al. (2005) identified *Dermatophagoides farina* as most abundant species in West Bengal than previously reported survey of Modak et al. (1991) from this state. So, information of regional faunas of the Acari is essential to our understanding of the global acarine diversity. A checklist of described species is necessary for understanding a fauna (Halliday, 1998; Halliday et al., 1999). However full checklists of House dust mites have been produced for only very few countries in the world (e.g. Italy by Bernini et al., 1995; Australia by Halliday, 1998; Mexico by Hoffmann and Lopez-Campos, 2000; New Zealand by Zhang and Rhode, 2003). India being a large country having differences in geographic and climate factors (temperature and humidity) from continental and oceanic climates, house dust mite species may be different in different regions in India (Valandiker and ChannaBasavanna, 1992; Kumar, 1988; Gill and Kaur, 2014). In West Bengal, a very few studies were conducted from last 20 years (Modak et al., 2004; Chaudhury et al., 2005; Kumar et al., 2014). So, monitoring of species diversity of a region enables estimation of the prospective functional roles of the species. In urban ecosystems, monitoring species diversity can be used as a tool to reduce human mismanagement and pollution in urbanized, industrial, rural, and managed areas (Wilson, 1997). Extending this view, the previous data are inadequate and old, without updated taxonomic information of dust mite species. So, the present study was aimed to assess the diversity of dust mite fauna of Kolkata, West Bengal, India. The results of the study are expected to supplement the necessary information on distribution and abundance of various species of dust mite in West Bengal. Information on the distribution and abundance of these mite species will also be helpful for a better refinement of their control. The present study also helps to identify the mite species which are common and abundant and have the potential to play an allergenic role and should be investigated further.

MATERIALS AND METHODS

Dust samples were collected from 20 houses located in and around Kolkata, West Bengal, from two different habitats, namely bed and bedroom floor once in a month during January 2017 to December 2017. The houses were selected from five different corners of the city namely East, West, North, South and Central region of Kolkata and each region contained four houses and the residents of the houses had history of nasobronchial allergic diseases and also did not use any acaricides during the study period. The verbal consent was taken from the heads of the family for collection of their house dusts. Written consent was obtained from head of the family of each house that they should not change their houses during the study period and also provided with a digital hygrometer and a thermometer for measuring relative humidity and temperature inside the house, respectively at the time of sampling. Floor dust was collected by sweeping the floor, while bed dust was collected by dusting the mattresses, bed linens and pillows on clean sheets of newspaper and kept in separate plastic packets and labelled properly and samples were immediately frozen to avoid mite multiplication. The dust samples were processed by first passing through a set of sieves of decreasing mesh size (2.36 mm., 1.00 mm., 500µ, 75µ, 45µ) in a mechanical sieve shaker for 20 minutes. The portion of dust that was retained in the sieve 75µ and 45 µ mesh size were processed following the flotation method of ChannaBasavanna et al. (1984), with some modifications. One gram of each dust sample was mixed with pure kerosene oil and stirred constantly for 10 mins. on a vortex mixture. The mixture was centrifuged at 2000 r.p.m. for two minutes and the supernatant was filtered using Whatman No.1 filter paper. A mixture of kerosene oil and carbon tetrachloride with specific gravity 1.3 was added to the sediment in the tube and after centrifugation, it was filtered on the same filter paper. This process was repeated twice with a mixture of kerosene oil and carbon tetrachloride having specific gravity 1.4 and 1.5, respectively. The supernatant was filtered again and the residue collected on the filter paper was washed with a fine jet of 70% alcohol and transferred to a Petridish. Mites were picked with a brush and these were mounted in Hoyer's medium. The same process was performed for rest of the dust samples.

Before the mites were identified, mounted slides were dried in an oven at 40°C for 10-15 days. Taxonomic identification was done under research microscope (Olympus CH-20i). Total number of each type of mites was summarized and percentage of each species of mites was calculated and the predominant species was determined. Total number of all the isolated mites was counted with the aid of a compound microscope Solarz (1997) including live mites, dead mites, and incomplete remains, and mite density was calculated as a number of specimens per 1 gram of dust.

The mites in all stages in each sample were counted and identified with the help of Hughes (1961), Krantz (1978), Colloff and Spieksma (1992) and Krantz and Walter (2009). All specimens were deposited in the Department of Zoology, University of Calcutta, 35, Ballygunge Circular Road, Kolkata-700019, West Bengal, India.

The diversity indices of the dust mite abundance were analyzed using Biodiversity Pro software (McAleece et al., 1997; Biodiversity Professional; Scottish Association for Marine Science and the Natural History Museum, London, UK). Species diversity was calculated using Shannon diversity index [H'= - Σ Pi lnPi) and Shannon Hmax (Hmax = Log10(S)], Shannon evenness was calculated using the formula; J = H' /Hmax, where, H'= information content of sample (bits/individual) or Shannon diversity index, and Pi = proportion of total sample belonging to i^{th} species, S =total number of species in habitat (species richness) (Magurran, 1988).

RESULTS

The present study revealed that the house dust mites were present in all the dust samples surveyed. A total of 51 species belonging to 34 genera and 17 families were identified from house dust as shown in Supp. Table S1. Among these species, only 3 species (*Dermatophagoides pteronyssinus, Blomia tropicalis* and *Cheyletus malaccensis*) were present in all houses.

The maximum number of species recovered was from the families Cheyletidae, Acaridae, Pyroglyphidae and Echimyopodidae. The cheyletids contain 10 species whereas acarids and pyroglyphids share 6 species, followed by Echimyopodidae which contains only 4 species (Table 1).

The pyroglyphid mite, *Dermatophagoides pteronyssinus* was the most dominating one with an average density of 673.35 ± 63.95 /gm dust followed by *Blomia tropicalis* from the family Echimyopodidae with an average mean density of 415.05 ± 162.73/ gm of dust. Another species of pyroglyphid mite, *D. farinae* and aeroglyphid mite, *Glycycometus geniculatus* were common but their average mean density were 157.15 ± 118.06/ gm dust and 117.9 ± 101.71/ gm dust, respectively, while others were present in less densities (Table 2, Fig. 1).

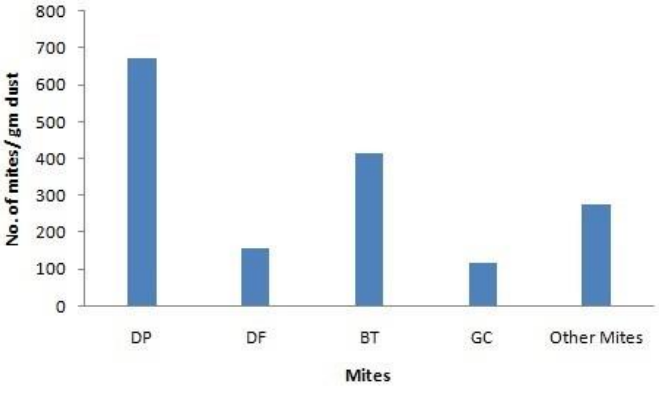

Figure 1. Abundance of four major mites DP (*Dermatophagoides pteronyssinus*), DF (*Dermatophagoides farina*), BT (*Blomia tropicalis*), GC (*Glycycometus domesticus*) along with other mites from Kolkata, West Bengal.

Table 1. House dust mites in different houses (n=20) in West Bengal, India.

House Dust Mite Species	H-1	H-2	H-3	H-4	H-5	H-6	H-7	H-8	H-9	H-10	H-11	H-12	H-13	H-14	H-15	H-16	H-17	H-18	H-19	H-20	Total
Suidasiidae																					
Suidasia nesbitti Hughes		+			+			+			+	+		+					+	+	8
Suidasia medanensis Oudemans	+	+		+			+			+		+				+	+				8
Acaridae																					
Tyrophagus putrescentiae (Schrank)	+	+		+	+		+	+	+				+	+			+			+	11
Tyrophagus longior (Geravis)	+		+	+			+	+	+		+	+			+		+	+		+	12
Tyroborus lini Oudemans							+							+					+		3
Acarus gracilis Hughes		+	+	+			+	+		+	+			+		+	+	+	+		12
Acarus siro Linnaeus	+	+	+	+	+			+			+	+								+	9
Neoacotyledon rhizoglyphoides (Zachvatkin)	+	+			+	+	+	+				+	+		+	+	+			+	12
Lardoglyphidae																					
Lardoglyphus zacheri Oudemans		+	+	+					+	+	+				+						7
Pyroglyphidae																					
Hirstia domicola Fain	+			+	+			+	+	+		+	+				+	+	+		11
Euroglyphus maynei Cooreman		+	+	+	+	+	+		+	+			+	+		+		+	+	+	14
Dermatophagoides farinae Hughes	+	+	+	+	+	+	+		+		+	+		+	+	+				+	14
D. pteronyssinus Trouessart	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	20
Sturnophagoides sp.*															+					+	20
Pyroglyphus sp.*					+						+								+		3
Glycyphagidae																					
Glycyphagus ornatus Kramer			+						+				+	+				+			5
Glycyphagus sp.*	+	+													+		+				4
Lepidoglyphus destructor (Schrank)		+	+		+	+	+				+		+	+			+			+	0
Aeroglyphidae																					
Glycycometus geniculatus Vitzthum	+	+				+	+	+		+	+	+	+					+	+	+	12

*They could not be identified to species level as they were immature or fragmented condition.

H: House

Table 1. Continued...

House Dust Mite Species	H-1	H-2	H-3	H-4	H-5	H-6	H-7	H-8	H-9	H-10	H-11	H-12	H-13	H-14	H-15	H-16	H-17	H-18	H-19	H-20	Total
Echimyopodidae																					
Blomia tropicalis Bronswijk (Bronswijk, Cock & Oshima)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	20
B. kulagini Zachvatkin		+		+			+		+										+		5
B. tijiboda Oudemans	+			+		+	+														4
B. freemani Hughes	+																+				2
Ascidae																					
Proctolaelaps sp. *			+												+					+	3
Lasioseius americanus Chant	+	+							+												3
L. mcgregori Chant							+									+					2
Phytoseiidae																					
Amblyseius longispinosus Evans *																		+	+		2
A. indicus Narayanan and Kaur *			+																		1
Ameroseiidae																					
Kleemannia plumosus Oudemans	+			+	+												+			+	5
Typhlodromus sp.																		+			1
Tydeidae																					
Pronematus mcgregori Baker							+	+					+	+							4
Tydeus sp.*						+						+	+								3
Stigmaeidae																					
Cheylostigmaeus sp.	+								+												2
Mediolata serrata Podder, Saha and Gupta																			+		1
M. simplex Wood			+	+			+	+	+				+					+	+		8
Cheyletidae																					
Cheyletus malaccensis Oudemans	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	20

*They could not be identified to species level as they were immature or fragmented condition.

H: House

Table 1. Continued...

House Dust Mite Species	H-1	H-2	H-3	H-4	H-5	H-6	H-7	H-8	H-9	H-10	H-11	H-12	H-13	H-14	H-15	H-16	H-17	H-18	H-19	H-20	Total
C. trouessearti Oudemans		+	+		+			+	+						+			+	+		8
C. carnifex (Zachvatkin)		+														+	+	+		+	5
Chelacaropsis moorei Baker					+		+			+	+			+	+				+	+	8
C. neomoorei Podder, Saha and Gupta							+														1
Acaropsis sollers Kuzin								+	+												2
Eucheyletia sp.*			+							+								+			3
Grallacheles indicus Podder, Gupta and Saha															+	+					2
Grallacheles bakeri De Leon			+													+		+	+		4
Tormbiculidae																					
Trombicula sp*		+			+														+	+	4
Tarosonemidae																					
Fungitarsonemus sp.*	+							+	+												3
Tarsonemus kolkataensis Podder, Gupta and Saha					+									+	+						3
Tarsonemus granarius Lindquist	+				+							+					+			+	4
Alycidae																					
Pachygnathus sp *				+	+				+				+				+				5
Raphignathidae																					
Raphignathus broomicus Podder, Gupta and Saha *sp. inq.*											+										1
Total Number of species	**22**	**19**	**16**	**20**	**21**	**11**	**20**	**19**	**20**	**12**	**13**	**15**	**15**	**15**	**16**	**13**	**16**	**18**	**21**	**21**	

*They could not be identified to species level as they were immature or fragmented condition.

H: House

Table 2. Number and % of positive house along with average densities of house dust mites per gram dust.

Species name	No. (% of positive house)	No. of mites/g. dust per house (Avg. ± S.D.)
Suidaseiidae		
Suidasia nesbitti Hughes	8 (40)	5.15 ± 6.54
Suidasia medanensis Oudemans	8 (40)	4.15 ± 4.34
Acaridae		
Tyrophagus putrescentiae (Schrank)	11 (55)	13.3 ± 12.46
Tyrophagus longior (Geravis)	12 (60)	15.15 ± 12.93
Tyroborus lini Oudemans	3 (15)	2.5 ± 6.11
Acarus gracilis Hughes	12 (60)	25.1 ± 21.39
Acarus siro Linnaeus	9 (45)	8.35 ± 10.21
Neoacotyledon rhizoglyphoides (Zachvatkin)	12 (60)	20.2 ± 17.65
Lardoglyphidae		
Lardoglyphus zacheri Oudemans	7 (35)	4.35 ± 6.34
Pyroglyphidae		
Hirstia domicola Fain	11 (55)	10.85 ± 10.19
Euroglyphus maynei Cooreman	14 (70)	14.05 ± 10.11
Dermatophagoides farina Hughes	14 (70)	157.15 ± 118.06
D. pteronyssinus Trouessart	20 (100)	673.35 ± 63.95
Sturnophagoides sp.*	2 (10)	0.7 ± 2.17
Pyroglyphus sp.*	3 (15)	0.8 ± 2.01
Glycyphagidae		
Glycyphagus ornatus Kramer	5 (25)	4.7 ± 8.43
Glycyphagus sp.*	4 (20)	1.5 ± 3.15
Lepidoglyphus destructor (Schrank)	10 (50)	19.05 ± 20.40
Echimyopodidae		
Blomia tropicalis (Bronswijk, Cock and Oshima)	20 (100)	415.05 ± 162.73
B. kulagini Zachvatkin	5 (25)	6.05 ± 11.03
B. tijiboda Oudemans	4 (20)	2.8 ± 5.86
B. freemani Hughes	2 (10)	1.35 ± 4.18
Aeroglyphidae		
Glycycometus geniculatus Vitzthum	12 (60)	117.9 ± 101.71
Ascidae		
Proctolaelaps sp.*	3 (15)	1.3 ± 3.21
Lasioseius americanus Chant	3 (15)	2.2 ± 5.46
L. mcgregori Chant	2 (10)	1.95 ± 6.01
Phytoseiidae		
Amblyseius longispinosus Evans*	2 (10)	1.4 ± 4.35
A. indicus Kaur	1 (5)	0.85 ± 3.80
Ameroseiidae		
Kleemannia plumosus Oudemans	5 (25)	4.8 ± 9.35
Typhlodromus sp.*	1 (5)	0.35 ± 1.56
Tydeidae		
Pronematus mcgregori Baker	4 (20)	2.65 ± 5.66
Tydeus sp.*	3 (15)	1.1±2.73
Stigmaeidae		
Cheylostigmaeus sp.*	2 (10)	1.15 ± 3.54
Mediolata serrata Podder, Saha and Gupta	1 (5)	0.25 ± 1.12
M. simplex Wood	8 (40)	3.6 ± 4.66
Cheyletidae		
Cheyletus malaccensis Oudemans	20 (100)	55.1 ± 48.53
C. trouessearti Oudemans	8 (40)	16.75 ± 23.94
C. carnifex (Zachvatkin)	5 (25)	5.15 ± 9.32
C. eruditus Schrank	5 (25)	2.75 ± 5.14
Chelacaropsis moorei Baker	8 (40)	5.7 ± 7.45

Table 2. Continued...

Species name	No. (% of positive house)	No. of mites/g. dust per house (Avg. ± S.D.)
Cheyletidae		
Chelacaropsis neomoorei Podder, Saha and Gupta	1 (5)	0.35 ± 1.56
Acaropsis sollers Kuzin	2 (10)	0.95 ± 2.96
Eucheyletia sp.*	3 (15)	0.7 ± 1.78
Grallacheles indicus Podder, Gupta and Saha	2 (10)	0.5 ± 1.67
Grallacheles bakeri De Leon	4 (20)	1.5 ± 3.17
Tormbiculidae		
Trombicula sp.*	4 (20)	0.6 ± 1.35
Tarosonemidae		
Fungitarsonemus sp.*	3 (15)	0.45 ± 1.23
Tarsonemus kolkataensis Podder, Gupta and Saha	3 (15)	0.35 ± 0.87
Tarsonemus granarius Lindquist	4 (20)	1.25 ± 3.11
Alycidae		
Pachygnathus sp.*	5 (25)	0.35 ± 1.18
Raphignathidae		
Raphignathus broomicus Podder, Gupta and Saha *sp. inq.*	1 (5)	0.2 ± 0.89

*They could not be identified to species level as they were immature or fragmented condition.

The cheyletid mite, *Cheyletus malaccensis*, was the most common and abundant species and had a comparatively higher density (55.1 mites / gm of dust) than other species in this group (Table 2).

Suidasia nesbitti and *S. medanensis* were the only two species of suidasiids that were found in house dust. The average density of both the species was 5.15 ± 6.54 and 4.15 ± 4.34, respectively.

Other mites identified from this study were from Ascidae, Phytoseiidae, Ameroseiidae, Tydeidae, Stigmaeidae, Trombiculidae, Tarsonemidae, Alycidae and Raphignathidae. Among these, the lardoglyphid, aeroglyphid, alycid, trombiculid and raphignathid contain only one mite species each (Table 2).

Among these 51 species, the mites marked with asterix, could not be identified to species level as they were immature or fragmented condition (Table 1).

Also two plant mite species identified in the current study; *Amblyseius indicus* and *A. longispinosus*. The occurrence of these species in house dust was probably accidental.

The species diversity, evenness and richness of house dust mites in twelve months were expressed by values of Shannon H', Shannon Hmax, and Shannon J indices (Table 2). The results indicated that the trends of maximum diversity and richness were found in November, while minimum was in April. In case of evenness, the maximum was in May and minimum in February. This may be due to the possibly changes in the temperature and the humidity (Table 3).

DISCUSSION

The allergen producing mites *Dermatophagoides pteronyssinus, D. farinae, Glycycometus geniculatus, Blomia tropicalis, Acarus siro, Glycyphagus domesticus, Euroglyphus mayenei, Tyrophagus putrescentiae* are found in dwellings around the world (Kronqrist et al., 2000; Arlian, 2002; Solarz et al., 2004; Szilman et al., 2006; Yadav et al., 2006). These mite species have also been found in the different houses of the present study.

Several studies on the house dust mite fauna have been conducted in different parts of the country upto now and reported varying number of different species of dust mites in the country. Gupta and Datta (1975) isolated 12 species of mites from 6 districts of West Bengal. Dixit and Mehta (1973) observed 7 species of mites from Madhya Pradesh. ChannaBasavanna et al. (1984) recorded 26 species of mites belonging to 6 families and 2 orders from Bangalore. Kumar et al. (1988) identified 27 species under 21 genera from Punjab. Valandiker and ChannaBasavanna (1992) made faunistic studies of house dust mites in Karnataka and reported 11 species under 8 genera and 6 families. Lakshmi and Haq (1999) reported 17 species under 13 genera from Calicut. In a recent study, Chaudhury et al. (2005) reported 25 mite species from West Bengal. Podder et al. (2005, 2006, 2009) described some new species and new records from house dust of Kolkata, West Bengal. Kumar et al. (2013) described 26 species of house dust mites belonging to 19 genera under 12 families. Gill and Kaur (2014) reported 14 species belonging to 11 genera under 7 families from Punjab.

The present study indicates that the fauna of house dust mites in West Bengal, India, is quite diverse and not only restricted by a few mite species in contrast to the reports available from other parts of the country. In this study, *Amblyseius longispinosus* which is predominantly a plant mite species and has been reported from the house dust on India or in Asia the first time. One possibility is that; this is the accidental appearance in house dust from ornamental plant which was placed in an earthen pot inside the houses. The presence of three mite families (Phytoseiidae, Stigmaeidae and Cheyletidae) that include a number of known predators of other mites is of particular

Table 3: The values of density indices of house dust mites in different months of Kolkata.

Index	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Shannon H' Log Base 10.	0.795	0.752	0.713	0.681	0.786	0.802	0.731	0.866	0.891	0.855	0.865	0.831
Shannon Hmax Log Base 10.	1.505	1.415	1.491	1.531	1.556	1.519	1.462	1.544	1.58	1.519	1.491	1.491
Shannon J'	0.528	0.532	0.478	0.445	0.505	0.528	0.5	0.561	0.564	0.563	0.58	0.557

interest. The result of the present study indicated that the presence of high percentage of predatory mite (*Cheyletus malaccensis*) in the all the houses surveyed may have role to maintain the ecological balance within the niche as they feed on other mites but their numbers are always lower than the other prey mites (Yoshikawa, 1985; Mariana et al*.,* 2000).

Observations on the house dust mite diversity provide information about the variations in the species richness and the evenness shaped by the temperature, humidity and the species interactions. Although the local determinants of the diversity such as competition, predation remained undetermined in the present study, grossly the different habitats influence the richness and the evenness of house dust mites in the different regions of West Bengal.

Dermatophagoides pteronyssinus was the most abundant mite recovered during the study and this species represented an average of 47% of total mites collected from house dust followed by *Blomia tropicalis* (16.6%) in West Bengal. The present study disagrees with the study of Mariana et al. (2000) from Malaysia, who opined that the *B. tropiocalis* is more abundant than *D. pteronyssinus*. This may be due to difference in local climatic factors which are responsible for their population growth (Colloff, 1992).

So, the allergenicity of *Acarus siro*, *Blomia tropicalis*, *Dermatophagoides pteronyssinus*, *D. farinae*, *Lepidoglyphus destructor* and *Tyrophagus putrescentiae* is well studied in West Bengal, India (Podder et al*.,* 2009, 2010a, 2018). However, the allergenicity of other mites is not well studied and characterised. Therefore, it is recommended that the allergenicity of other mites which are reported to be allergenic around the world, isolated from house dust, should be evaluated among the West Bengal population.

This study showed that West Bengal is extremely rich in house dust mite fauna because of ideal temperature and relative humidity are prevailing in this part of the country (Modak et al*.,* 2004; Podder et al., 2009, 2010b). Spieksma (1970), Wharton (1970), Bronswijk and Sinha (1971) and Aykut et al. (2016) also observed that a temperature varying between 18-30^{o}C and RH 75-80% are ideal for the multiplication and growth of house dust mite.

This study showed the occurrence of a very rich assemblage of house dust mite species and also established the prevalence of high populations of allergenic mites in the houses of West Bengal. Undoubtedly, these allergenic mites might play a significant role in the incidence of respiratory problems in West Bengal. However, to generate in-depth information in this regard, there is a need to carry out more studies in different corners of this country.

Authors' contribution

Sanjoy Podder: Conceptualization, project administration, formal analysis, writing - original draft. **Himani Biswas:** Data collection, investigation, formal analysis. **Goutam Kumar Saha:** Supervision, formal analysis, writing - review & editing.

Statement of ethics approval

The authors state that ethical permission is not required for investigation on diversity of the mites and collection of house dusts in India.

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Conflict of interest

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

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RESEARCH ARTICLE

Rotundabaloghia (*Rotundabaloghia*) *dogani* sp. nov. from Hong Kong (Acari: Mesostigmata: Rotundabaloghiidae)

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ABSTRACT: *Rotundabaloghia* (*Rotundabaloghia*) *dogani* **sp. nov.** is described based on three females and one male collected from soil in Tai Po Kau Nature Reserve, in Hong Kong. The new species differs from the other species from the subgenus *Rotundabaloghia* in the shape and length of the ventral setae.

Keywords: Mite, Taxonomy, South-East Asia.
Zoobank: http://zoobank.org/4C72C121-E7E2-42F2-A69A-4C17737D73AD

INTRODUCTION

The *Rotundabaloghia* (*Rotundabaloghia*) Hirschmann, 1975 is an endemic subgenus in South-East Asia and in Austral-Asian region, the members of this taxon are described from New Guinea, suthern parts of Japan, Taiwan, Philippines, Indonesia and Hong Kong (Kontschán, 2010, 2015, Kontschán & Kiss, 2015). This subgenus is well characterized by the three or four pairs of short and needle-like setae on rows *j–J* on dorsal body among the lot of long and apically pilose setae, contrary with the sister-group (*Rotundabaloghia* (*Circobalogia*) Kontschán, 2010) where these short and smooth dorsal setae are absent (Kontschán, 2010).

Till today only three Uropodina mites are presented from area of Hong Kong, all from the family Rotundabaloghiidae Kontschán, 2010 (Kontschán, 2015) and only one species belongs to this subgenus (*R.* (*R.*) *hongkongensis* Kontschán, 2015).

During my last visit to Natural History Museum of Geneva some soil samples from Hong Kong were also investigated. One of the samples contained several specimens of rotundabaloghiid mites, described herein as second species from this subgenus from Hong Kong.

MATERIALS AND METHODS

The specimens examined were cleared in lactic acid for a week and afterwards, the specimens were investigated on half-covered deep slides with a Leica 1000 microscope. Drawings were made with the aid of a drawing tube on a Leica 1000 microscope. All measurements and the scale bars in the figures are given in micrometres (µm).

All specimens are stored in ethanol and deposited in the Natural History Museum of Geneva.

Abbreviations

v = ventral setae, *st* = sternal setae, *ad* = adanal setae, *p* = pores, *lf* = lyriform fissures.

RESULTS

Rotundabaloghia (*Rotundabaloghia*) *dogani* sp. nov.

Zoobank: http://zoobank.org/3083E06F-F613-4729-B2B9-9479030B463C

(Figures 1-7).

Diagnosis. Dorsal shield covered by oval pits, dorsal setae long and apically pilose except three pairs of short and needle-like setae on central area. All ventral setae smooth and needle-like, setae *st1* short, setae *v2* and *v6* shorter than *v7* and *v8*.

Material examined. *Holotype.* Female. SBH-96/17, Hong Kong (New Territories), Tai Po Kau Nature Reserve, after the big picnic area soil sampled near a dead but still standing tree, 150 m a.s.l.; 9.XII.1996; leg. B. Hauser (soil extraction by means of a Berlese funnel in Geneva). *Paratypes.* Two females and one male, collection data as in holotype.

Description

Female (n=3).

Description. Length of idiosoma 325–335, width 265–280. Shape circular, posterior margin rounded, colour reddish brown.

Dorsal idiosoma (Fig. 1). Marginal and dorsal shields fused. Majority of dorsal setae basally curved and apically pilose (ca 36–39), except three pairs of short (ca 9–10) and smooth setae on rows *j–J*. Four pairs of lyriform fissures and two pairs of pore-like organs situated on central and centrolateral areas of dorsal shield. Surface of dorsal shield covered by oval pits (ca 4–5×4–6).

Ventral idiosoma (Fig. 2). Sternal shield covered by some oval pits (ca 4–5×4–5). All sternal setae smooth and needle-like, *st1* and *st4* short (ca 4–5), *st2* and *st3* long (ca 7–11). Setae *st1* situated at level of anterior margin of coxae II, *st2* at level of posterior margin of coxae II, *st3* at level of central area of coxae III, *St4* at level of anterior margin of

coxae IV. All ventral setae smooth and needle-like, *v2* and *v6* ca 8–10, *v7* ca 17–18, *v8* ca 23–25 and adanal setae ca 16–17 long. Setae *v2* situated near basal edges of genital shield, *v7* and *v8* situated at level of setae *ad*. Setae *v6* situated between *v2* and *v8*. Setae *ad* placed lateral to anal opening, at level of its anterior margin. Ventral shield covered by oval pits (ca 5–6×5–6), but smooth around anal opening. One pair of lyriform fissures situated close to setae *v2*. Peritremes (Fig. 2) with a short straight post-stigmatid part and a longer hook-shaped prestigmatid part. Stigmata situated between coxae II and III. Genital shield wide, linguliform (108–110 long and 55–58 wide at base), without apical process. Surface of genital shield covered by oval pits (ca 4–6×5–6). Pedofossae deep, their surface smooth, separate furrows for tarsi IV present. Base of tritosternum narrow, vase-like, tritosternal laciniae smooth, subdivided into three smooth branches in its distal half.

Gnathosoma. Corniculi horn-like, internal malae smooth and as long as corniculi. Hypostomal setae *h1* long (ca 9–13), smooth and needle-like. Other setae and other parts not visible, covered by coxae I.

Legs (Figs 3–6). All legs with smooth and needle-like setae, the claws on first leg absent. All femora bearing flap-like ventral processes. Leg I 190–195, leg II 195–205, leg III 195–205, leg IV 200–210.

Male (n=1).

Length of idiosoma 325, width 275.

Dorsal idiosoma. Ornamentation and chaetotaxy of dorsal shield as for female.

Ventral idiosoma (Fig. 7). Four pairs of sternal setae (*st1*–*st4*) situated anterior to genital shield, *st5* placed lateral to genital opening. Setae *st1*, *st4* and *st5* short (ca 4–7), *st2* and *st3* long (ca 12–13) all sternal setae smooth and needle-like. All ventral setae smooth and needle-like, *v2* and *v6* ca 13–15, *v7* and *v8* ca 22–26 and adanal setae ca 17–18 long. Positions of ventral setae same as in females. Ventral shield covered by oval pits (ca 4–5×4–6), but smooth around anal opening. One pair of lyriform fissures situated close to setae *v2*. Other characters as in female. Genital shield oval (27×28) and situated between coxae IV.

Larva and nymphs. Unknown.

Etymology. I dedicated the new species to my dear friend and the founder of the Acarological Studies, Dr. Salih Doğan.

Remark. Currently only three rotundabaloghiid species were described from Hong Kong (Kontschán, 2015), namely *Angolubaloghia staryi* Kontschán, 2015, *Rotundabaloghia (Rotundabaloghia) hongkongensis* Kontschán, 2015 and *Depressorotunda (Depressorotunda) taurina* Kontschán 2015. The new species differs in some characters from the previously described ones. The *R. (R.) dogani* does not have ventral cavity, contrary with the *D.* (*D.*) *taurina*, where it is well-developed. The genital shield of the new species is linguliform, but it is triangular in the case of *A. staryi*. The setae *v8* is very short and *v2* very long in *R.* (*R.*) *hongkongensis*, but the new species bears short *v2* and long *v8* setae.

Updated key for the *Rotundabaloghia* (*Rotundabaloghia*) species (modified, after Kontschán, 2015).

1, Setae *v8* smooth 2
– Setae *v8* not smooth 8
2, Setae *v8* shorter than other ventral setae 6
– Setae *v8* similar in length to *v7* 3
3, Setae *v2* and *v6* shorter than *v7* and *v8* ..... *R.* (*R.*) *dogani* **sp. nov.**
– Setae *v2* and *v6* similar in length to *v7* and *v8* 4
4, Setae *v7* longer than other ventral seta ..... *R.* (*R.*) *kaszabi* Hirschmann, 1975
– Setae *v7* as long as other ventral setae 5
5, Scupltural patter between setae *v7* present ..... *R.* (*R.*) *makilingoides* Hirschmann & Hiramatsu, 1992
– Scupltural patter between setae *v7* absent ..... *R.* (*R.*). *makilingensis* Hirschmann & Hiramatsu, 1992
6, Setae *v6* as long as *v8* ..... *R.* (*R.*) *hongkongensis* Kontschán, 2015
– Setae *v6* longer than *v8* 7
7, Setae *v8* as long as *ad* ..... *R.* (*R.*) *korsosi* Kontschán, 2008
– Setae *v8* shorter than *ad* ..... *R.* (*R.*) *hirschmanni* Hiramatsu, 1977
8, Setae *ad* pilose ..... *R.* (*R.*) *baloghi* Hirschmann, 1975
– Setae *ad* smooth 9
9, Setae *v7* pilose 10
– Setae *v7* smooth 11
10, Setae *st1*, *st2* and *st3* much longer (10×) than *st4* ..... *R.* (*R.*) *macroseta* Hirschmann, 1975
–Setae *st1*, *st2* and *st3* not much longer (4×) than *st4* ..... *R.* (*R.*) *mahunkai* Hirschmann, 1975
11, Seate *st1* longer and wider than *st2* and *st3* ..... *R.* (*R.*) *monomacroseta* Hirschmann, 1975
– Setae *st1* not longer and wider than *st2* and *st3* 12
12, Setae *v7* two times longer than *ad* ..... *R.* (*R.*) *kaszabisimilis* Hirschmann, 1975
– Setae *v7* as long as *ad* ..... *R.* (*R.*) *pilosa* Hirschmann, 1975

Statement of ethics approval

Not applicable.

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Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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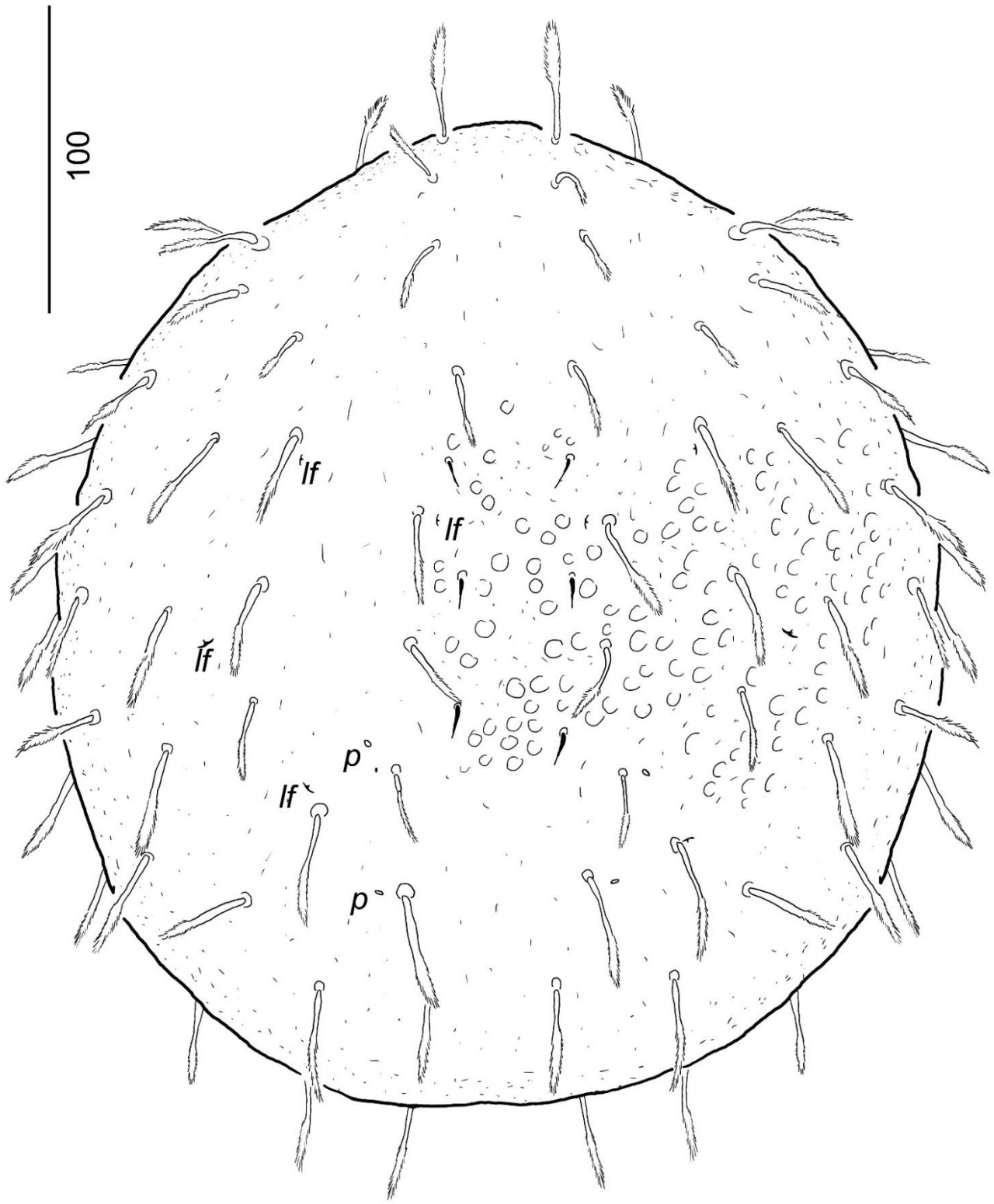

Figure 1. Dorsal view of *Rotundabaloghia* (*Rotundabaloghia*) *dogani* **sp. nov.** female, holotype.

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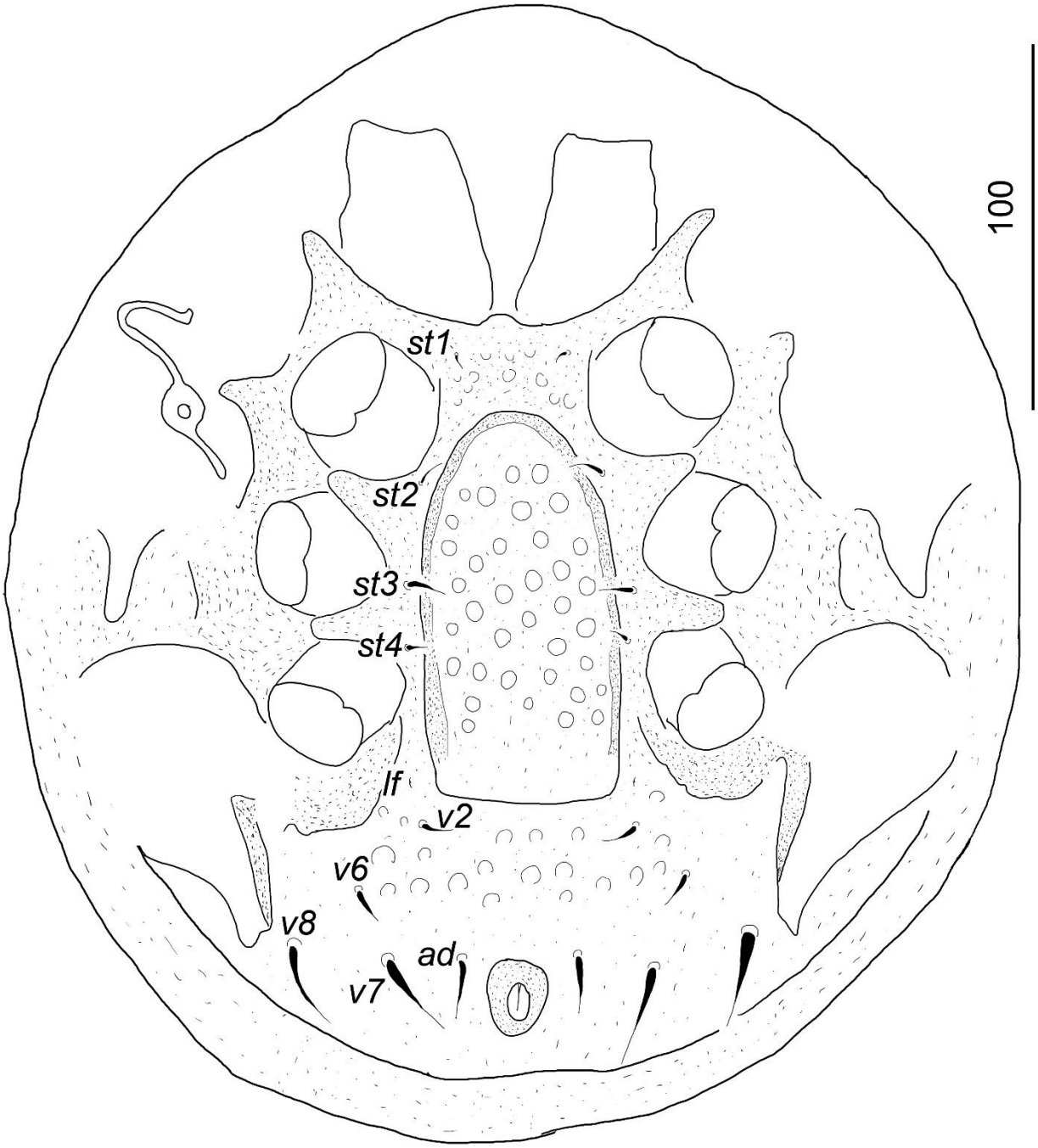

Figure 2. Ventral view of *Rotundabaloghia* (*Rotundabaloghia*) *dogani* **sp. nov.** female, holotype.

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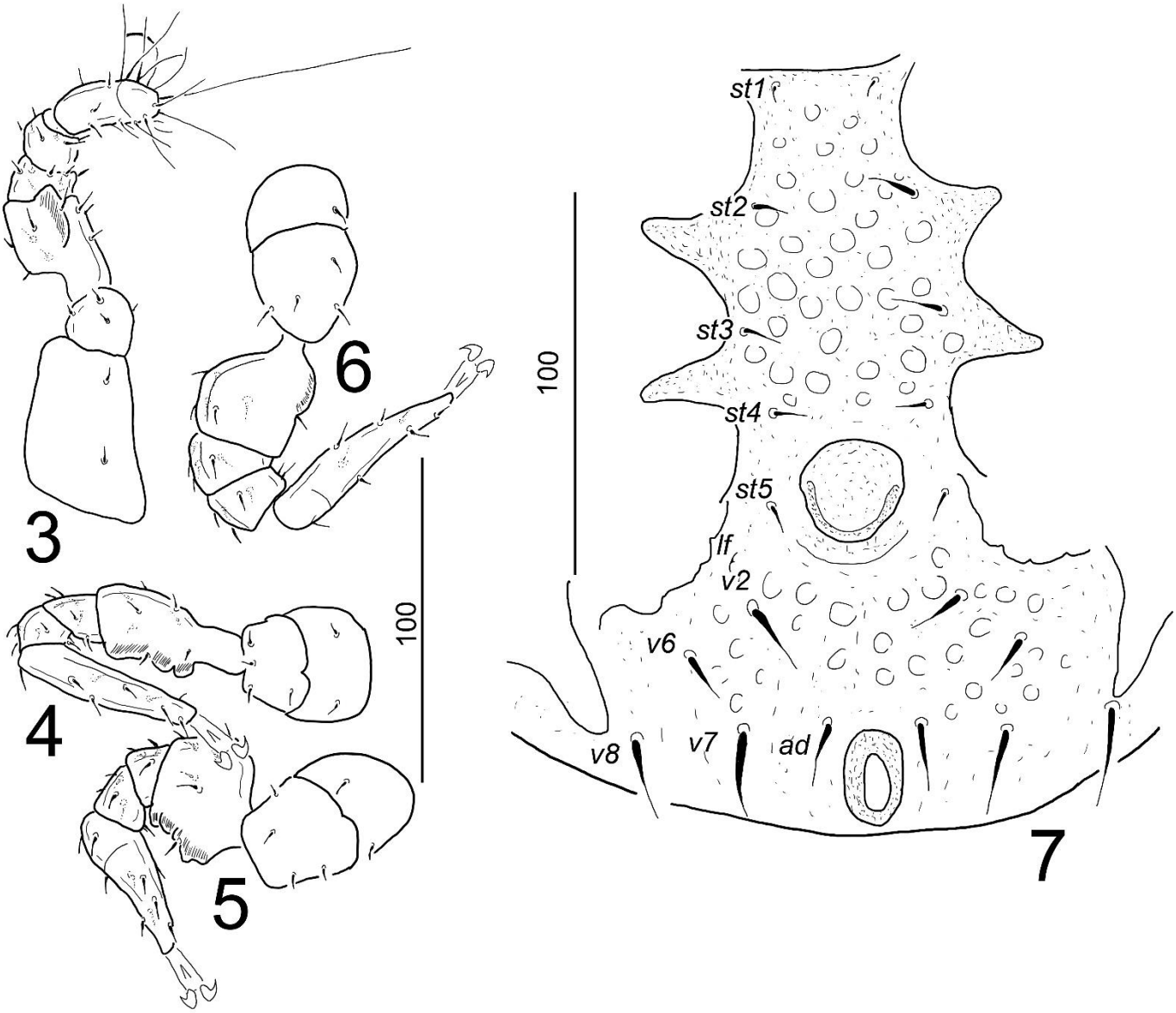

Figures 3-7. *Rotundabaloghia* (*Rotundabaloghia*) *dogani* **sp. nov.** female, holotype. **3.** Leg I. in ventral view, **4.** Leg II in ventral view, **5.** Leg III in ventral view, **6.** Leg IV in ventral view, **7.** Intercoxal area of male paratype.

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RESEARCH ARTICLE

Mites of the genus *Prozercon* (Acari: Zerconidae) in Dilek Peninsula-Büyük Menderes Delta National Park (Turkey), with description of a new species

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ASBTRACT: In the present paper, zerconid mites of the genus *Prozercon* were collected from the Dilek Peninsula-Büyük Menderes Delta National Park, Didim County, Aydın Province (western Turkey). After identification processes, three *Prozercon* species were found in the research area, among them, *P. didimensis* **sp. nov.** was described and illustrated as a new species for the science. Also, altitude and habitat preferences of the species were given and discussed.

Keywords: Mesostigmata, zerconid mites, new species, preference, Didim, Aydın.
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INTRODUCTION

Zerconid mites (Zerconidae), which is one of the important mite families of soil mesofauna in the Holarctic region, are represented with two genera (*Prozercon* and *Zercon*) and 129 species in Turkey (Urhan and Karaca, 2019, 2020; Urhan et al., 2020, 2021; Bulut, 2020; Keçeci, 2020). Most of these species are endemic to Turkey and have been found during long-term researches in the country, especially based on various results of M.Sc. and Ph.D. theses. On the other hand, in many parts of Turkey systematics and ecological researches are still ongoing on zerconid mites. Therefore, new species and records of zerconid mites are being increased day by day for the Turkish fauna.

National parks are protected areas in many countries in the world which include various kinds of floral and faunal elements, and are always great attractions for scientists. Turkey is a rich country in terms of number of national parks with 44 national parks, one of which is the Dilek Peninsula-Büyük Menderes Delta National Park, a protected area located in Kuşadası County of Aydın Province (western Turkey). No research on zerconid mites has been performed in this area so far. Therefore, the aim of this study is to reveal the species diversity of the family Zerconidae in that area systematically and ecologically.

In the present paper, diversity of these mites in the above-mentioned national park was investigated. A species list for the *Prozercon* species found in that area was given herein, including knowledge on their distributions, altitudinal and habitat preferences. Also, description and illustrations of a new species and a key for the *Prozercon* species in the research area were given.

MATERIALS AND METHODS

All materials of zerconid mites were collected from the Dilek Peninsula-Büyük Menderes Delta National Park in a period between December 2018 and May 2020 as part of a faunistic study. Sampling studies was carried out after obtaining legal permissions from the "Republic of Turkey Ministry of Forestry and Water Affairs, General Directorate of Nature Conservation and National Parks (72784983-488.04-51504)". For revealing species richness of zerconid mites in the research area, different materials (plant litter, soil and moss samples) were collected from suitable habitats, especially from forestland areas. All materials were taken from 97 different localities. The GPS data for collecting localities, including coordinates and altitudes, was taken using a Garmin GPSMap 62S.

All collected samples were transferred to the acarology laboratory of Pamukkale University for identification processes. Firstly, all collected materials were put in the Berlese-Tullgren funnels for extraction of mite specimens during 5-7 days. Zerconid specimens were selected using an Olympus SZ51. Then, they were preserved in 70% ethanol, cleared in 60% lactic acid, and finally mounted on microscope slides using Hoyer's medium. The specimens were identified using an Olympus CX41 and all illustrations were drawn with DP25 camera attached to an Olympus BX50 microscope. All examined *Prozercon* specimens were deposited at acarology laboratory of Pamukkale University, Denizli, Turkey. The idiosomal setation follows Lindquist and Evans (1965), with modifications for the caudal region as given by Lindquist and Moraza (1998). Terminology for idiosomal adenotaxy and poroidotaxy follows that of Johnston and Moraza (1991). All measurements, including scale bars of the figures, are given in micrometers (μm). Abbreviation of DN was used for deutonymph specimens.

RESULTS

Family Zerconidae Canestrini, 1891

Genus *Prozercon* Sellnick, 1943

Type species: *Zercon fimbriatus* C. L. Koch, 1839

Posterior parts of peritremal shields extending to setae *R4* or *R5*. Two setae present on peritremal shields: *r1* short, smooth or finely plumose, *r3* short and smooth. No gap between peritremal shield and the edge of the podonotum. Adgenital shields absent. Opisthonotum with seven or eight pairs of marginal setae (*S1* + *R1–R6* or *S1* + *R1–R7*). Anterior margin of ventrianal shield always with two setae (Karaca et al., 2017).

Prozercon didimensis **sp. nov.** (Figures 1-2)

Zoobank: http://zoobank.org/8395C5CC-80D5-4BDE-8D8C-C51DE33169E2

Type material. Holotype (female), soil and litter samples under strawberry tree (*Arbutus* sp.), 37°29.664' N, 27°20.381' E, 85 m a.s.l., vicinity of Söke-Milas road, fork of Didim road, Aydın Province, 8 April 2020. Paratypes: 6 females, same data as holotype; 5 females, soil and litter samples under olive tree (*Olea europaea*), same data as holotype.

Diagnosis. Anterior margin of ventrianal shield with two pairs of setae. All podonotal setae finely barbed (except seta *j5*). Seta *j5* short, smooth and needle-like. All opisthonotal setae finely barbed in various lengths, marginal setae shorter than others. Pores *gdS2* located between setae *Z2* and *S2*, *gdZ3* located between setae *J4* and *Z4*, closer to *Z4*. Dorsal cavities weakly developed. Podonotum covered with tile-like and reticulate pattern, opisthonotum covered by irregular punctate pattern.

Female (Figs 1–2). Length (without gnathosoma) and width in holotype 305 and 232, respectively. Measurements of 11 paratypes: length 296–315, width 224–247. Dorsal fossae indistint and weakly sclerotized.

Dorsal side. (Fig. 1). Twenty pairs of setae present on podonotum: setae in *j* series with six pairs, *z* series with five pairs, *s* series with six pairs and *r* series with three pairs. All of them finely or densely plumose (except seta *j5*). Setae *j1* and *s3* markedly elongated, densely plumose and brush-like. Seta *j5* short, smooth and needle-like. Setae *j2*, *s1* and *z2* shorter than other podonotal setae. Remaining podonotal setae approximately as the same length. Except seta *s3*, all marginal setae in *r* series situated as parallel to lateral margin of podonotum. Twenty one pairs of setae present on opisthonotum: setae in *J* series with five pairs, *Z* series with five pairs, *S* series with five pairs and *R* series with six pairs. All of them finely or densely plumose. In *J* series, only seta *J5* reaching base of following seta. Seta *Z5* unilateral plumose in contrary of other setae in *J* series, situated as parallel to posterior margin of opisthonotum. None of setae in *Z* series reaching the base of following seta. Seta *JV5* similar to *Z5*. None of setae in *S* series reaching the base of following seta. All setae in *S* series situated as parallel to lateral margin of opisthonotum. Seta *S2* not reaching lateral margin of opisthonotum, seta *S3* reaching lateral margin of opisthonotum, but setae *S4* and *S5* reaching beyond of opisthonotum. All marginal setae (*S1* + *R1–R6*) situated as parallel to lateral margin of opisthonotum. The interval between setae *Z5* and *JV5* 21–24. Length of the opisthonotal setae and distance between setal bases within longitudinal *J*, *Z* and *S* rows are given in Table 1 for female specimens of *P. didimensis* **sp. nov.**

Pores. (Fig. 1). On podonotum, pores *gds1* located on the line connecting setae *j3–s1*, closer to *s1*. Pores *gdj4* located on the line connecting setae *j4–z4*, closer to *z4*. Pores *gds4* located on the line connecting setae *s4–s5*, closer to *s5*. On opisthonotum, pores *gdZ1* located above the base of setae *Z1*. Pores *gdS2* located on the line connecting setae *Z2–S2*. Pores *gdZ3* located on the line connecting setae *J4–Z4*, closer to *Z4*. Pores *gdS5* located closer to base of setae *S5*.

Ventral side. (Fig. 2). Chaetotaxy and shape of the peritrematal shields normal for the genus *Prozercon*. Posterolateral tips of peritrematal shield reaching the level of setae *R2–R3*. Peritrematal shield with two pairs of setae (*r1* and *r3*), both short, smooth and needle-like. Peritremes similar to reverse comma. Sternal shield with three pairs of setae (*st1–3*), genital shield with one seta (*st5*), and one seta (*st4*) present between sternal and epigynal shield, all of them short, smooth and needle-like. Glands *gv2* absent between posterior section of genital shield and anterior section of ventrianal shield. Ventrianal shield with eight pairs of setae (*JV1–JV3*, *ZV2–ZV4*, *JV4* and *Ad*) and one single postanal seta (*Pa*), all short, smooth and needle-like. Postanal seta as the longest on the ventrianal shield. Anterior margin of ventrianal shield with two setae (*JV1*).

Male and immature stages. Not found.

Etymology. The specific epithet '*didimensis*' refers to the Didim County (Aydın Province) where the new species was collected.

Remarks. *Prozercon didimensis* **sp. nov.** is quite similar to *P. banazensis* Urhan, Karaca and Duran, 2015, *P. erdogani* Urhan, 2010 and *P. martae* Ujvári, 2010. The distinctive morphological features of these four species were given in Table 2.

Table 1. Maximum and minimum ranges of opisthonotal setae and the distances between their bases in *J*, *Z*, and *S* rows of *Prozercon didimensis* **sp. nov.** (females).

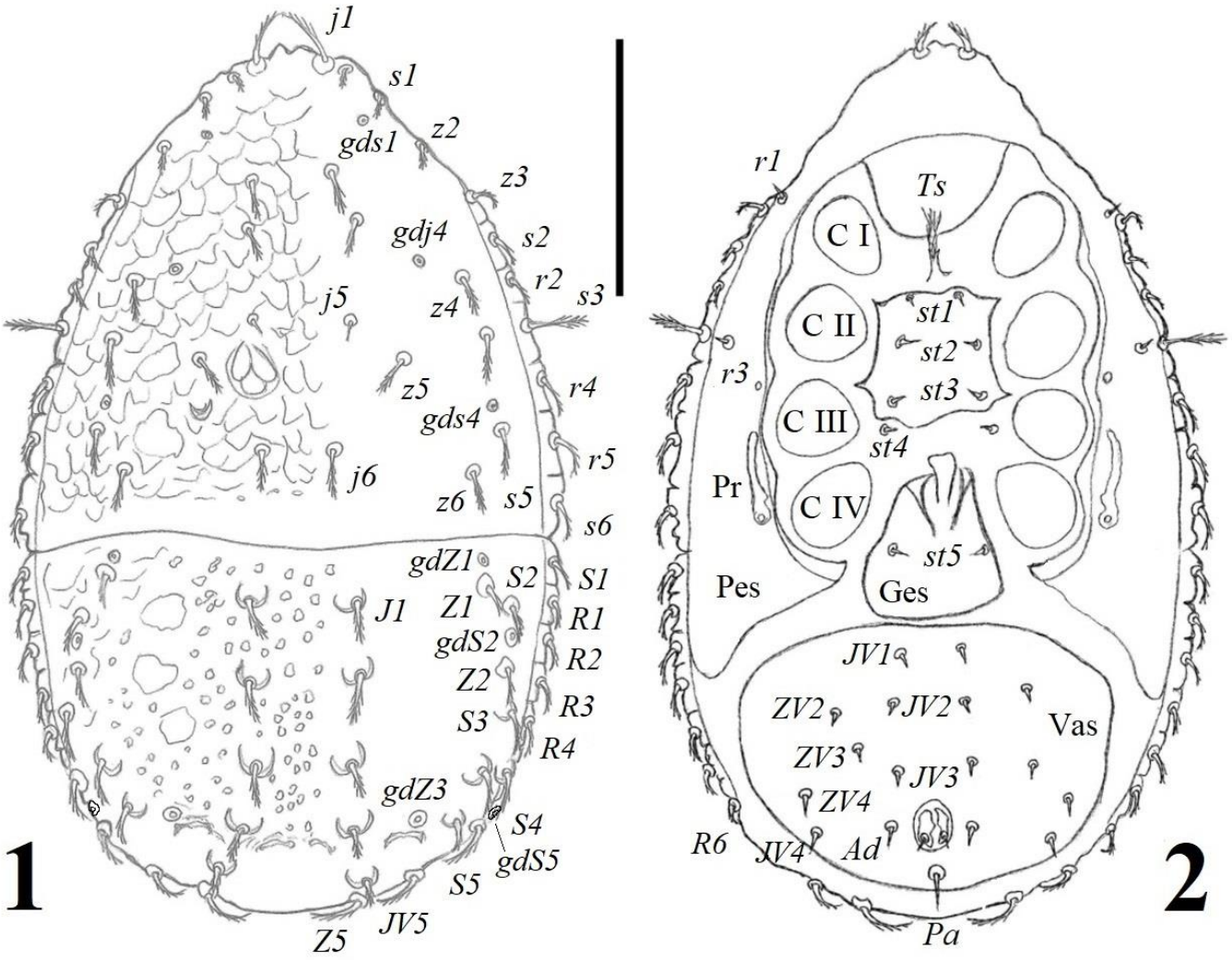
Setae	♀	Setae	♀	Seta	♀
J1	20–21	***Z1***	16–18	***S1***	18–22
J1–J2	25–31	***Z1–Z2***	35–38	***S1–S2***	20–25
J2	22–26	***Z2***	15–18	***S2***	18–20
J2–J3	30–37	***Z2–Z3***	29–34	***S2–S3***	31–35
J3	18–21	***Z3***	18–20	***S3***	18–19
J3–J4	22–27	***Z3–Z4***	17–23	***S3–S4***	22–29
J4	15–16	***Z4***	11–12	***S4***	18–21
J4–J5	18–21	***Z4–Z5***	45–56	***S4–S5***	18–22
J5	12–15	***Z5***	17–20	***S5***	20–23

Prozercon yavuzi Urhan, 1998

Materials examined: Three females: soil and litter samples under oak tree (*Quercus* sp.), 37°39.598' N, 27°6.434' D, 814 m a.s.l., vicinity of radar surveillance area of "Naval Forces Command", 10 December 2018. Nine females: soil and litter samples under sage-leaved rock-rose (*Cistus salviifolius*), 37°44.784' N, 27°20.967' D, 200 m a.s.l., vicinity of Söke-Davutlar neighborhoods road, 14 May 2019. One female: soil and litter samples under Turkish pine (*Pinus brutia*), 37°38.899' N, 27°15.744' D, 10 m a.s.l., Yuvacaköy neighborhood, 14 May 2019. Four females and two males: soil and litter samples under olive tree (*Olea europaea*), 37°37.283' N, 27°11.763' D, 12 m a.s.l., vicinity of Tuzburgazı neighborhood, 14 May 2019. One female: soil and litter samples under oleaster-leafed pear (*Pyrus elaeagrifolia*), 37°41.121' N, 27°17.595' D, 892 m a.s.l., Dilek Mountain, 31 August 2019. One female: soil and litter samples under kermes oak (*Quercus coccifera*), 37°42.213' N, 27°17.990' D, 385 m a.s.l., vicinity of Kurşunlu Monastery, Davutlar neighborhood, 9 November 2019. Six females: soil and litter samples under holly oak (*Quercus ilex*), 37°42.624' N, 27°18.512' D, 277 m a.s.l., vicinity of Kurşunlu Monastery, Davutlar neighborhood, 9 November 2019. One female: moss samples, 37°41.798' N, 27°9.436' D, 21 m a.s.l., vicinity of Kavaklıburun Bay, 3 February 2020.

Turkish distribution: Aydın, Balıkesir, Denizli, İstanbul, Muğla (Karaca, 2015, 2021).

Known distribution: Turkey (Urhan, 1998), Crete, Greece (Ujvári, 2008, 2011).



Figures 1–2. *Prozercon didimensis* **sp. nov.** (female) **1.** Dorsal view, **2.** Ventral views. Abbreviations: (*r1* and *r3*) peritremal setae, (Pr) peritreme, (Pes) peritremal shield, (Ts) tritosternum, (C I–C IV) endopodal shields, (*st1–5*) sternal setae, (Ges) genital shield, (Vas) ventrianal shield, (*JV1– JV3*, *ZV2–ZV4* and *JV4*) ventrianal setae, (*Ad*) adanal setae and (*Pa*) postanal seta. Scale bar 100.

Table 2. Morphological distinguishing characters for *P. didimensis* **sp. nov.,** *P. banazensis*, *P. erdogani* and *P. martae*.

Characters	*P. didimensis* sp. nov.	*P. banazensis* Urhan, Karaca and Duran, 2015	*P. erdogani* Urhan, 2010	*P. martae* Ujvári, 2010
Setae in *J* series	Only seta *J5* reach to base of following seta	Except setae *J1* and *J2*, *J3–J5* reach to base of following seta	Except setae *J1* and *J2*, *J3–J5* reach to base of following seta	Except setae *J1*, *J2–J5* reach to base of following seta
Seta *J6*	situated as parallel to posterior margin of opisthonotum	situated as parallel to posterior margin of opisthonotum	situated vertically to posterior margin of opisthonotum	situated vertically to posterior margin of opisthonotum
Seta *Z3*	finely barbed	phylliform and finely serrate marginally	plumose	plumose
Seta *S2*	finely barbed	finely barbed	plumose	plumose
Seta *S3*	finely barbed	phylliform and finely serrate marginally or smooth	absent	plumose
Seta *S4*	situated as parallel to lateral margin of opisthonotum	situated vertically to lateral margin of opisthonotum	situated vertically to lateral margin of opisthonotum	situated vertically to lateral margin of opisthonotum
Pore *Po2*	located between setae *Z2* and *S1*	located between setae *S1* and *R3*, closer to *S1*	located between setae *Z2* and *S1*	inside the line connecting *Z2* and *S1*, closer to *S1*
Pore *Po3*	located between setae *J4* and *Z4*	located between setae *J4* and *Z3*	located between setae *J3* and *Z4*	located under the line connecting *Z3* and *S3*

Table 3. Altitude preferences of *Prozercon* species in the Dilek Peninsula-Büyük Menderes Delta National Park.

Altitudinal ranges (m)	*P. didimensis* sp. nov.	*P. umidicola* Urhan, 2002	*P. yavuzi* Urhan, 1998
0–50			
50–100	+		
100–150			+
150–200			
200–250			+
250–300			+
300–350			+
350–400			
400–450			
450–500		+	+
500–550			
550–600			
600–650			+
650–700			
700–750			
750–800			
800–850			+
850–900			
900–950			
950–1000			

Table 4. Habitat preferences of *Prozercon* species in the Dilek Peninsula-Büyük Menderes Delta National Park.

Habitat types	*P. didimensis* sp. nov.	*P. umidicola* Urhan, 2002	*P. yavuzi* Urhan, 1998
Olea europaea	+	+	
Pistacia sp.	+		
Pinus brutia			+
Pinus nigra			+
Quercus sp.			+

Key to *Prozercon* species in the Dilek Peninsula-Büyük Menderes Delta National Park

1 All marginal setae on opisthonotum pilose or plumose. Seta *S4* present …… **2**

1′ All marginal setae on opisthonotum (except seta *S1*) short, smooth and needle-like. Seta *S4* absent …… *P. yavuzi* Urhan, 1998

2 Marginal setae on opisthonotum with seven pairs (*S1* + *R1–R6*), seta *Z5* situated as parallel to posterior margin of opisthonotum …… *P. didimensis* **sp. nov.**

2′ Marginal setae on opisthonotum with seven pairs (*S1* + *R1–R7*), seta *Z5* situated as vertically to posterior margin of opisthonotum …… *P. umidicola* Urhan, 2002

Altitude preferences of *Prozercon* species in the Dilek Peninsula-Büyük Menderes Delta National Park

All materials for the *Prozercon* species were collected from suitable forestland areas at the altitude from 0 to 1000 m a.s.l. All sampling areas were divided according to 50 meters elevation ranges. After identification processes in the laboratory, the altitudinal distribution results of the *Prozercon* species were marked in Table 3.

According to Table 3, *P. didimensis* **sp. nov.** occurs only at lower altitudes (50–100 m a.s.l.). In addition, *P. umidicola* was only found at 450–500 m a.s.l. zones. However, since *P. yavuzi* showed a wide range of occurrences from 100 to 850 m a.s.l., it has no clear preference in terms of altitudinal ranges, but can live in low to mid-land areas.

Habitat preferences of *Prozercon* species in the Dilek Peninsula-Büyük Menderes Delta National Park

Samplings for *Prozercon* species were carried out in 97 different localities and the following 23 habitat types, mostly tree species, were noted: broom (*Genista* sp.), carob (*Ceratonia siliqua*), fern (*Pteridium aquilinum*), hawthorn (*Crataegus* sp.), juniper (*Juniperus* sp.), mastic (*Pistacia* sp.), moss (unspecified), mullein (*Verbascum* sp.), myrtle (*Myrtus communis*), oak (*Quercus* sp.), oleaster-leafed pear (*Pyrus elaeagrifolia*), olive (*Olea europaea*), pine (*Pinus brutia* and *P. nigra*), raspberry (*Rubus* sp.), rockrose (*Cistus* sp.), shrub (*Daphne gnidioides*), strawberry tree (*Arbutus* sp.), sycamore (*Platanus orientalis*), tamarisk (*Tamarix* sp.), thorn (*Paliurus spina-christi*), thorny burnet (*Sarcopoterium spinosum*) and walnut (*Juglans regia*). Habitat preferences of *Prozercon* species were marked in Table 4.

According to Table 4, all *Prozercon* specimens were found only in five different habitats (*Olea europaea*, *Pistacia* sp., *Pinus brutia*, *P. nigra* and *Quercus* sp.). In the remaining habitats, no specimens of *Prozercon* were found.

Authors' contributions

Büşra Keçeci: Investigation, collection of specimens (lead), methodology (equal), writing - original draft (supporting), preservation. **Raşit Urhan:** Funding acquisition, methodology (equal), project administration, supervision (lead), collection of specimens (supporting), identification, illustration. **Mehmet Karaca:** Data curation, formal analysis, methodology (equal), supervision (supporting), writing - original draft (lead), writing - review & editing, collection of specimens (supporting).

Statement of ethics approval

Not applicable.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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RESEARCH ARTICLE

A new record for the mite fauna of Turkey: *Molothrognathus shirazicus* (Acari: Caligonellidae) and the first description of its protonymph

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ASBTRACT: *Molothrognathus shirazicus* Khanjani, Bakhshi and Khanjani, 2016 is founded for the first time from Turkey and new report to the mite fauna of Turkey. The female and protonymph specimens of the species are collected from soil and litter under *Pinus brutia*, *P. nigra*, *Olea europaea*, *Paliurus spina-christi*, *Pistacia terebinthus* and *Verbascum* sp., Afyonkarahisar, Manisa, İzmir and Antalya provinces, Turkey. Also, the protonymph stage of *M. shirazicus* is described for the first time in this study. A key to all known species of the genus *Molothrognathus* of Turkey is given.

Keywords: Prostigmata, Raphignathoidea, *Molothrognathus*, new report, Turkey.
Zoobank: http://zoobank.org/18B9D939-0EEA-4DBB-AAC5-57E2050268BD

INTRODUCTION

Members of the family Caligonellidae (Acari: Raphignathoidea) are free-living predatory mites that feed on small arthropods and found in various habitats (Khanjani et al., 2016; Akyol, 2018; Amini et al., 2018; Doğan and Doğan, 2020), and with a world-wide distribution (Fan and Zhang, 2005). This family contains 5 genera and 67 species in the world (Doğan and Doğan, 2020). The genus *Molothrognathus* Summers and Schlinger belongs to the family Caligonellidae, so far contains 27 known species in the world, and is represented with 6 species in Turkey, viz. *M. bahariensis* Ueckermann and Khanjani, *M. crucis* Summers and Schlinger, *M. kamili* Doğan, *M. phytocolus* Meyer and Ueckermann, *M. terrulentus* Meyer and Ueckermann and *M. venusta* (Khaustov and Kuznetzov) (Koç and Ayyıldız, 1997; Doğan, 2003, 2019; Akyol and Koç, 2012; Doğan and Doğan, 2020). In this study, a new record of Turkish fauna *Molothrognathus shirazicus* Khanjani, Bakhshi and Khanjani is illustrated and described based on the adult females and protonymph.

MATERIALS AND METHODS

The specimens were collected from soil and litter under *Pinus brutia, P. nigra* (Pinaceae), *Olea europaea* (Oleaceae), *Paliurus spina-christi* (Rhamnaceae), *Pistacia terebinthus* (Anacardiaceae) and *Verbascum* sp. (Scrophulariaceae), in Afyonkarahisar, Manisa, İzmir and Antalya provinces, Turkey, and taken to the laboratory in plastic bags and extracted by Berlese-Tullgren funnels for 7 days. Mites were collected in 70% ethanol and mounted on slides in modified Hoyer's medium. The mite specimens were measured and drawn by means of a research microscope (Nikon Eclipse E 400). The setal nomenclature follows those of Kethley (1990) and Grandjean (1944). The drawn specimen's measurements were given first and followed by range of measurements (minimum-maximum) of other specimens in parentheses. All measurements were given in micrometres (μm). Measurements of legs were taken from base of femur to tips of tarsal claws. The specimens are deposited as slide-mounted in the (CBZM), Manisa, Turkey. See Zhang (2018) for abbreviations.

RESULTS

Family: Caligonellidae Grandjean, 1944

Genus: *Molothrognathus* Summers and Schlinger, 1955

Type species. *Molothrognathus leptostylus* Summers and Schlinger, 1955

Diagnosis. Peritremes originating medially on stylophore, immediately behind the cheliceral stylet bases.

Molothrognathus shirazicus Khanjani, Bakhshi and Khanjani, 2016

Diagnosis. Dorsum with smooth shield between setae *vi* and *d*1; palp-tibia with three setae; setae *sce* longest; tarsi 15(+1ω)-10(+1ω)-9-9 (Khanjani et al., 2016).

Female (n= 18) (Figure 1)

Length of body (excluding gnathosoma) 320 (315-325), width 190 (164-190).

Gnathosoma (Figs 1 A,B,G,H). Subcapitulum with two pairs of adoral setae (*or*1-2) and one pair of subcapitular setae *m* 36 (36-42). Stylophore conical. Tibial claw of palp about as long as palp-tarsus. Length of palp 143 (143-156). Number of setae and solenidia from palp-trochanter to palp-tarsus: 0, 1, 1, 3+1 well-developed claw, 3+1ω+4 eupathidia. Peritremes as depicted in Fig. 1H.

Dorsum of idiosoma (Fig. 1A). Dorsum with striae; 3 pairs of cupules present, *ia* behind posterior eye, *im* laterad of the setae *d* and *ip* laterad of setae *f*; prodorsum with smooth shield and two pair of eyes. All dorsal setae are

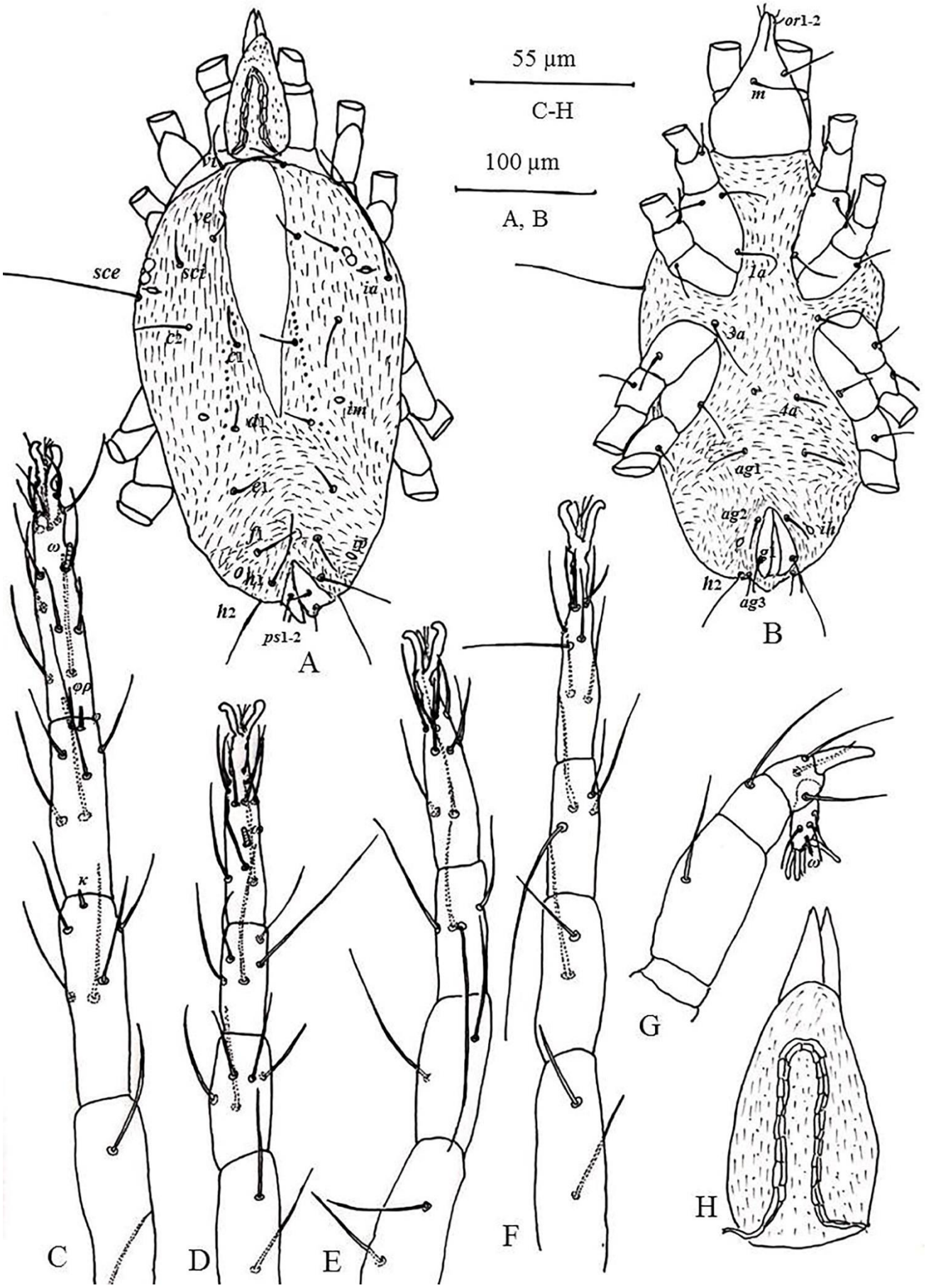

Figure 1. *Molothrognathus shirazicus* Khanjani, Bakhshi and Khanjani (Female) – **A.** Dorsal view of idiosoma, **B.** Ventral view of idiosoma, **C.** Leg I, **D.** Leg II, **E.** Leg III, **F.** Leg IV, **G.** Palp, **H.** Stylophore.

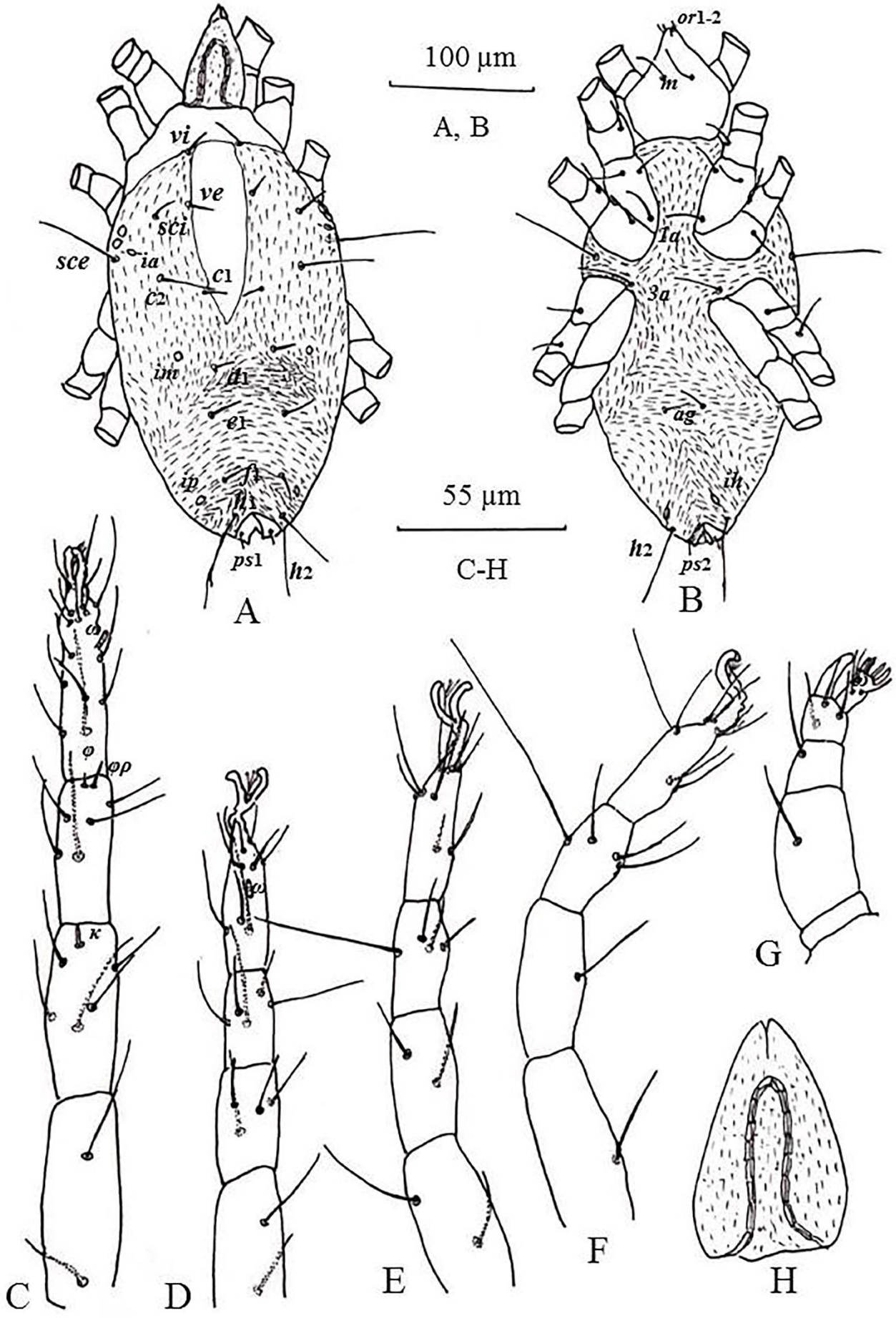

Figure 2. *Molothrognathus shirazicus* Khanjani, Bakhshi and Khanjani (Protonymph) – **A.** Dorsal view of idiosoma, **B.** Ventral view of idiosoma, **C.** Leg I, **D.** Leg II, **E.** Leg III, **F.** Leg IV, **G.** Palp, **H.** Stylophore.

simple. Length of dorsal setae: *vi* 26 (21-26), *ve* 21 (18-21), *sci* 21 (21), *sce* 78 (78-91), *c*1 16 (16), *c*2 36 (34-36), *d*1 16 (16), *e*1 32 (18-23), *f*1 26 (26), *h*1 52 (52-55), *h*2 49 (49-52). Distances between dorsal setae: *vi-vi* 44 (39-44), *vi-ve* 47 (47-49), *ve-ve* 55 (52-55), *ve-sci* 26 (26-29), *sci-sci* 107 (104-107), *sci-sce* 34 (31-34), *sce-sce* 151-172, *sce-c*1 70 (62-70), *c*2-*c*2 104 (96-104), *c*1-*c*1 36 (34-36), *c*1-*d*1 52 (52), *d*1-*d*1 47 (39-47), *d*1-*e*1 47 (39-47), *e*1-*e*1 65 (52-65), *e*1-*f*1 47 (31-47), *f*1-*f*1 42 (36-42), *f*1-*h*1 26 (23-26), *h*1-*h*1 29 (21-29), *h*2-*h*2 44 (36-44).

Venter of idiosoma (Fig. 1B). Ventral surface striated; endopodal shields absent; ventral setae three pairs: 1*a* 36 (31-36), 3*a* 42 (39-42) and 4*a* 16 (16-18); 1*a* located on coxae I, but 3*a* and 4*a* located on integument; aggenital region with three pairs of setae, *ag*1 21 (21-26), *ag*2 16 (16-18) and *ag*3 8 (8-10); genital valves with one pair of setae *g* 13 (13-16); one pair of cupules (*ih*) located lateral to setae *ag*1. Anal shields posteriorly with two pairs of setae (*ps*1-2).

Legs (Figs 1C-F). Length of legs: I 234 (234-239), II 169 (169-174), III 198 (198-208), IV 216 (216-234). Setal formulae of leg segments I–IV (solenidia not included and in parentheses): coxae 3-1-1-1, trochanters 1-1-1-1, femora 2-2-2-2, genua 5(+1κ)-5-2-2, tibiae 5(+1φ+ 1φρ)-5-4-4, tarsi 15(+1ω)-10(+1ω)-9-9. Lengths of solenidia: Iω 6 (6-8), IIω 5 (5-6), Iφρ 7 (7), Iφ 3 (3-4), Iκ 4 (4).

Protonymph (n= 1) (Figure 2)

Length of body (excluding gnathosoma) 286, width 161.

Gnathosoma (Figs 2 A,B,G,H). Length of palp 112, palp chaetotaxy as in female. Subcapitulum one pair of subcapitular setae (*m* 39). Peritremes as depicted in Fig. 2H.

Dorsum of idiosoma (Fig. 2A). Dorsal setae, cupules, shield area and striae similar to that of adult female. Length of dorsal setae: *vi* 21, *ve* 18, *sci* 21, *sce* 78, *c*1 16, *c*2 36, *d*1 16, *e*1 23, *f*1 26, *h*1 52, *h*2 49. Distances between dorsal setae: *vi-vi* 39, *vi-ve* 31, *ve-ve* 39, *ve-sci* 21, *sci-sci* 96, *sci-sce* 39, *sce-sce* 143, *sce-c*1 65, *c*2-*c*2 96, *c*1-*c*1 36, *c*1-*d*1 42, *d*1-*d*1 39, *d*1-*e*1 42, *e*1-*e*1 52, *e*1-*f*1 42, *f*1-*f*1 36, *f*1-*h*1 26, *h*1-*h*1 26, *h*2-*h*2 36.

Venter of idiosoma (Fig. 2B). Ventral surface striated; endopodal shields absent; 1*a* 31, 3*a* 34; one pair of aggenital setae *ag* 13; setae 4*a*, other aggenital setae, genital shields and its setae absent.

Legs (Figs 2 C-F). Length of legs: I 192, II 143, III 161, IV 174. Setal formulae of legs I–IV (solenidia not included and in parentheses): coxae 3-1-1-0, trochanters 1-1-1-0, femora 2-2-2-1, genua 5(+1κ)-4-2-1, tibiae 5(+1φ+ 1φρ)-5-4-4, tarsi 15(+1ω)-10(+1ω)-9-8. Lengths of solenidia: Iω 6, IIω 4, Iφρ 6, Iφ 3, Iκ 4.

Male, *deutonymph and larva*. Unknown.

Material examined. Twelve females collected from litter and soil under the *Pinus nigra*, 1200 m a.s.l., Emirdağı mountains, B. Karabağ village, Bolvadin district, Afyonkarahisar province, 08 June 2019; one female from litter and soil under *Verbascum* sp., 130 m a.s.l., Salihli district, 23 June 2019, two females from litter and soil under *Paliurus spina-christi*, and one female from litter and soil under *Olea europaea*, 71 m a.s.l., Muradiye area, Yunusemre district, Manisa province, 27 September and 22 October 2019; two females from litter and soil under *Pistacia terebinthus*, 10 m a.s.l., Patara Beach, Kaş district, Antalya province, 12 July 2019; one protonymph from litter and soil under *Pinus brutia*, 110 m.a.s.l., Gümüldür- Menderes road 7 km, Menderes district, İzmir province, 24 July 2019; Turkey, coll. M. Akyol.

Remarks

Molothrognathus shirazicus Khanjani, Bakhshi and Khanjani, 2016 was described for the first time from Iran and collected from soil under *Populus euphratica* (Salicaceae) and *Platycladus orientalis* (Cupressaceae), in Shiraz (altitude 1552 m a.s.l.), Fars province, Iran (Khanjani et al., 2016). In this study the samples collected from soil and litter under new host plants including *Pinus brutia*, *P. nigra*, *Olea europaea*, *Paliurus spina-christi*, *Pistacia terebinthus* and *Verbascum* sp. (altitude 10-1200 m a.s.l.) in Afyonkarahisar, Manisa, İzmir and Antalya provinces, Turkey.

Body size of 335 (278) long and 201 (120–136) wide in the Iranian specimens; 320 (315-325) long and 190 (164-190) wide in the Turkish specimens. Body size of the Turkish specimens is almost similar to the Iranian specimens.

The Turkish specimens resemble the Iranian specimens, but some measurements of body setae (*m* 36-42, *4a* 16, *c*1 16, *c*2 34-36, *d*1 16 in the Turkish specimens) are different from the type specimens (*m* 45-50, *4a* 23-28, *c*1 17-21, *c*2 40-51, *d*1 17-21 in the Iranian specimens).

Only female of *M. shirazicus* was found from the type locality (Iran) (Khanjani et al., 2016). This is the second report of this species and a new record for the Turkish fauna. Also, the protonymph stage of *M. shirazicus* is described for the first time in this study.

Key to *Molothrognathus* species of Turkey

1. Dorsal integument with simple striae 2
- Dorsal integument with dual striae .....*M. kamili* Doğan
2. Prodorsum without shield medially 3
- Prodorsum with shield medially or finely striated spindle shaped shield - like area..... 4
3. Setae *sce* and *c*2 much longer than other dorsal setae; tarsi I-IV with 15(+1ω)-10(+1ω)-9-9 setae .....
.....*M. bahariensis* Ueckermann and Khanjani
- Almost all dorsal setae subequal; tarsi I-IV with 14(+1ω)-9(+1ω)-8-8 setae .....
.....*M. venusta* (Khaustov and Kuznetzov)
4. Prodorsum with finely striated spindle shaped shield - like area .....*M. phytocolus* Meyer and Ueckermann
- Prodorsum with shield medially 5
5. Setae *sce* as long as *c*2.....
.....*M. terrulentus* Meyer and Ueckermann
- Setae *sce* and *c*2 not equally long 6

6. Setae *c*2 shorter than *sci* and *ve* ....*M. crucis* Summers and Schlinger
- Setae *c*2 longer than *sci* and *ve* .... *M. shirazicus* Khanjani, Bakhshi and Khanjani

Statement of ethics approval

Not applicable.

Funding

There is no fund for the present study.

Conflict of interest

No potential conflict of interest was reported by the author.

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SHORT NOTE

A new record of the genus *Sperchon* (Acari: Hydrachnidia, Sperchontidae) from Turkey

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ABSTRACT: A new water mite *Sperchon* (*Hispidosperhcon*) *beckeri* Bader and Sepasgosarian, 1984 is recorded for the first time from Elazığ province, Turkey. This species is characterized by the P-2 with long finger-shaped ventral projection and P-4 with well-developed ventral tubercles.

Keywords: Mite, *Sperchon*, new report, Elazığ, running water.
Zoobank: http://zoobank.org/01ADDFFC-87BB-4A67-9780-1CFF756BCC02

Water mites of the genus *Sperchon* Kramer, 1877 have been found in all biogeographic regions except for Australia and Antarctica. It is widely distributed in the Holarctic, Oriental and Ethiopian regions (Cook, 1974).

Up to now, only 19 species belong to the genus have been described from Turkey (Erman et al., 2010, 2019; Esen et al., 2010): During a survey of the freshwater fauna of Eastern Turkey (Elaziğ Province), one new record of the water mite genus *Sperchon* Kramer was detected from running waters. The aim of this paper is to contribute sperchontid water mites in Turkey.

Samples were collected by hand netting, sorted on the spot from the living material, fixed in Koenike's fluid and dissected as described elsewhere (e.g. Gerecke et al., 2007). The specimens are deposited in the research collection of the Biology Department, Bingöl University, Bingöl, Turkey.

The composition of the material is given as: (males/females/deutonymphs). All measurements are given in µm. The following abbreviations are used: Ac-1 = first acetabulum, Cx-I = first coxae, Cxgl–4 = coxoglandulare 4, dc-1–4 = dorsocentralia 1–4, dl-1–7 = dorsoglandularia 1–7, dL = dorsal length, L = length, W = width, %L = relative length, I-Leg-6 = Leg 1, sixth segment (tarsus), P-1 = palp, first segment.

Family Sperchontidae Thor, 1900

Genus *Sperchon* Kramer, 1877

Sperchon (*Hispidosperchon*) *beckeri* Bader and Sepasgosarian, 1984 (Figures 1-3)

Specimens examined. Elazığ province (Turkey), Alacakaya district, Halkalı Village, spring and low order streams, 38°32'44" N, 39°56'22" E, 1507 m a.s.l., 23.08.2020, (2/3/0); Elazığ province (Turkey), Arıcak district, Akdağlar mountain, low order streams, 38°37'56" N, 40°08'00" E, 2145 m a.s.l., 05.07.2018, (4/8/1). One male was dissected and slide-mounted in Hoyer's fluid.

Diagnosis. Integument ventrocaudally with fine denticles arranged in hexagonal pattern, dorsum with six pair and one medially muschle attachment plates. Cx-I+II medially not fused, Cx-III without coxoglandularia. Excretory pore smooth. Capitulum with short rostrum, P-2 with well-developed finger-shaped ventrodistal projection; P-4 shorter than P-3, with two well developed ventral tubercles close to each other, each bearing peg-like and at the tip rounded setae, the proximal tubercle larger, located in the centre of the segment, the distal one minor, located in the distal part.

Description. Integument dorsally and ventrally with fine denticles arranged in a hexagonal pattern (Fig. 3C); these denticles laterally and caudally inflating to form small rounded papillae; these papillae regularly-arranged, in juveniles these papillae covered whole of dorsal surface (Fig. 3A). Dorsum with six pairs and one medially muscle attachment plates both males and females (Fig. 1A). Ventral view of Cx-I+II medially close to each other, but not fused (Fig. 1B). Cx-III without a medial glandular opening (Cxgl-4). Ac-1-2 longish, Ac-3 round. Posterior part of the venter with a small unpaired postgenital platelet. Excretory pore smooth. Capitulum (Fig. 3D) with short rostrum; palps (Figs 1C-D, 2A, 3D); P-1 without dorsal seta; P-2 distoventrally with a long projection at its tip bearing three fine setae, one long and two short; dorsally bearing about 18-20 stout setae, some of them plumose. P-3 bearing about 12 stout setae and 10 fine setae, all restricted to the dorsal part; P-4 shorter than P-3, with the two well developed ventral tubercles close to each other, each bearing peg-like, at the tip rounded setae, the proximal one larger, located in the centre of the segment, the distal one larger, located in the distal part; P-5 short, with strong distal claws; Leg segments slender, III-/IV-L with a few short, simple dorsal setae; ambulacrum with claw blade well protruding, bearing a long dorsal and a shorter ventral clawlet (Fig. 1F).

Male (n=3): Idiosoma L 552-770, W 489-661; distance between posterior edge of Cx-IV 432-533. Genital valves L 138-207, pregenital sclerite forming an acute triangle; L Ac-1–3 50-63, 55-80, 43-57; Capitulum L 202-321; chelicera (Fig. 1E) L 198-310, basal segment L 126-240 claw L

55-70, L ratio chelicerae basal segment/claw 3.42-3.60; palp (Figs 1 C,D) total L 443-577, dL: P-1, 20-22; P-2, 108-124; P-3, 139-196; P-4, 135-188; P-5, 37-47; %L: P-1, 3.8-4.5; P-2, 24.4-21.5; P-3, 31.4-34.0; P-4, 30.5-32.6; P-5, 8.1-8.6; P-2/P-4 ratio 0.7-0.8. Leg segments L: I-Leg- 1-6: 60-75, 62-80, 93-112, 138-179, 132-158, 120-146; IV-Leg-1-6: 102-145, 106-134, 122-153, 237-298, 230-288, 207-224.

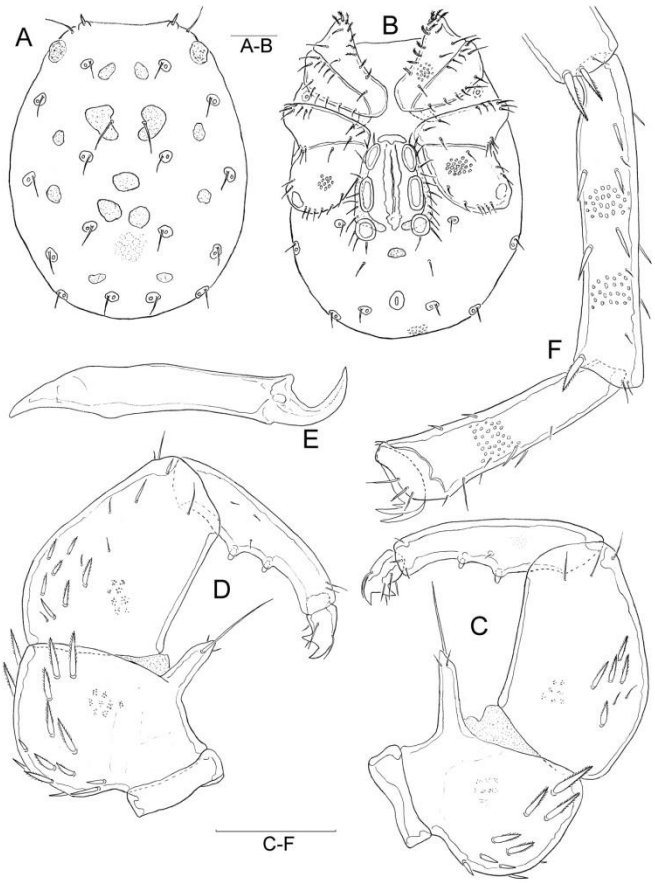

Figure 1. *Sperchon beckeri* (Male) – **A.** Idiosoma, dorsal view, **B.** Idiosoma, ventral view, **C.** Palp, medial view, **D.** Palp, lateral view, **E.** Chelicera, **F.** IV-L-5-6 (Scale bars= 100 µm).

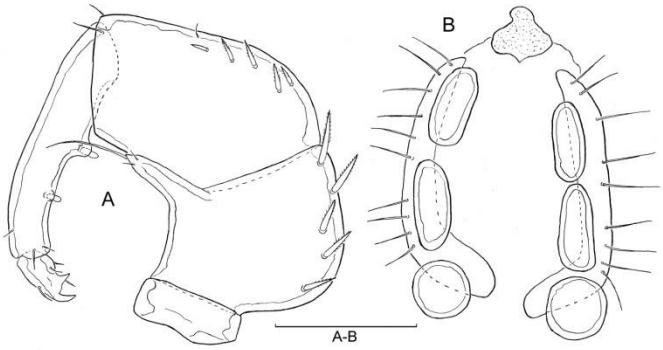

Figure 2. *Sperchon beckeri* (Female) – **A.** Palp, medial view, **B.** Genital field (Scale bar = 100 µm).

Female (n=3): Idiosoma L 942-1490, W 670-1145; distance between posterior edge of Cx-IV 520-685. Genital valves (Fig. 2B) L 180-246; pregenital sclerite forming a drop shaped; L Ac 1–3 51-68, 55-97, 48-67. Capitulum L 230-291; chelicera L 226-298, basal segment L 160-216, claw L 66-82, L ratio chelicerae basal segment/claw 2.42-2.63; palp (Fig. 2A) total L 440-612 dL and %L (in parentheses): P-1, 22-30 (5.0); P-2, 110-149 (24.3-25.0); P-3, 140-204 (31.8-33.3); P-4, 132-182 (29.7-30.0); P-5, 36-54 (8.2-8.8); P-2/P-4 ratio 0.8. Leg segments L: I-Leg-1-6: 68-72, 80-83, 95-109, 152-173, 147-156, 140-160; IV-Leg-1-6: 121-141, 120-135, 140-164, 267-302, 250-280, 211-242.

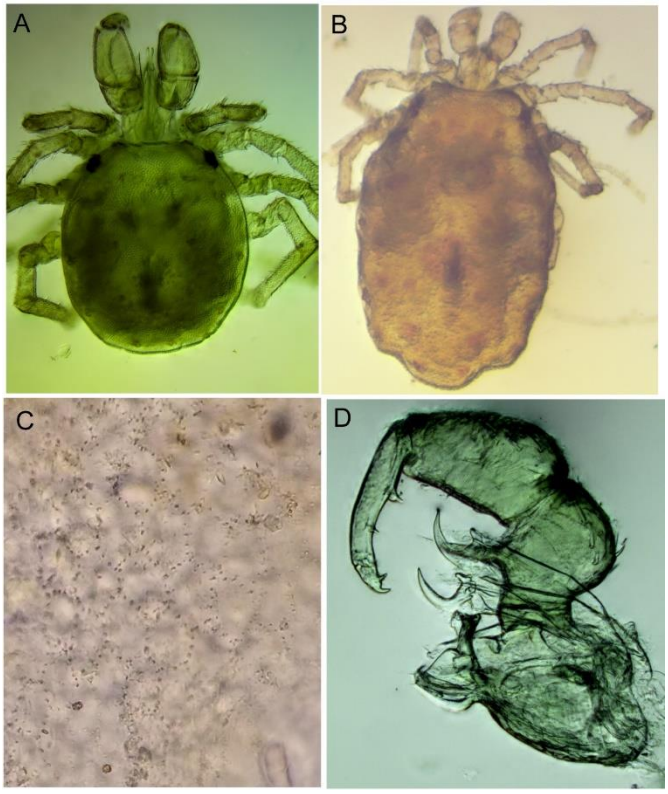

Figure 3. *Sperchon becheri*, (A, male; B-D, female) – **A.** Dorsal view, **B.** Dorsal view, **C.** Integument, ventrally, **D.** Gnathosoma (No scale bar).

Habitat. Low order streams, running waters near the springs, in the moss vegetation.

Distribution. Known from Iran (Mazaran and Karaj) (Bader and Sepasgosarian, 1984; Pešić et al., 2004) and Turkey (Elazığ) (current study).

Discussion. Having reticulated integument both dorsal and ventral side, absence of coxoglandularia of Cx-III, P-2 with long finger-shaped ventral projection and P-4 with well developed ventral tubercles our specimens agreed with original description of the species *Sperchon beckeri* Bader & Sepasgosarian, 1984. However, the Turkish specimens are different by the third pair of genital acetabula rounded (the third pair of genital acetabula more or less triangular). Pešić et al. (2004) recorded the species second time from Mazandaran Province after its original description (Bader and Sepasgosarian, 1984). This is third record of this species after above mentioned records from Iran.

Statement of ethics approval

Not applicable.

Funding

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Conflict of interest

No potential conflict of interest was reported by the author.

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