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Original paper

Ectoparasites of the common gundi (*Ctenodactylus gundi* Rothmann) from the Aures Region, Algeria

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ABSTRACT. *Ctenodactylus gundi* were captured in the southern region of Aures, Algeria from December 2015 through June 2017 to assess their ectoparasite diversity. 63.5% of the gundi had one or more ectoparasites, while 36.5% had none. Eight species of ectoparasites were identified. The most abundant taxa were species of *Neotrombicula* (61.5%), *Trombicula* (10.6%), and *Caenopsylla mira* (4.8%). The mean intensity for arachnids follows*: Neotrombicula* spp. (14.3), *Trombicula* spp. (10.6), and *Rhipicephalus* (*Boophilus) annulatus* (1.6). Among arachnids, mean intensity of males was greater than females in contrast to that of the flea *C. mira*, whose mean intensity for females was 4.8 compared to that of males with 2.8. *C. mira* and *Xenopsylla cheopis* have previously been reported on the gundi, while the mites *Neotrombicula* spp., *Trombicula* spp., *Eulaelaps stabularis*, *O. bacoti*, the tick *Rh.* (*Boophilus*) *annulatus* and the louse *Polyplax serrata* are reported here for the first time. Prevalence was influenced by host sex and was higher in males than females. The highest prevalence was recorded in species of *Neotrombicula* (39.2%) and *Trombicula* (20.3%). The abundance of these ectoparasites was directly influenced with climatic conditions specially with temperature (P=0.0002), and air humidity (P=0.0014).

Keywords: flea, infestation rate, louse, mite, prevalence

Introduction

Rodents are widely distributed globally and live in different environments and conditions [1]. Rodents comprise 42% of the world's mammalian biodiversity [2]. Thirty-one species of rodents occur in Algeria [3] to include three of the five known species of the gundi (*Massoutiera mzabi*, *Ctenodactylus gundi* and *C. vali*) [4,5]. *Ctenodactylus gundi* is the focus of this paper. In Algeria, *C. gundi* has been documented in the Saharan Atlas Mountains, from the Tunisian border in the east to Messâad in the west [6]. *C. gundi* is a diurnal desert species, which frequents rocky habitats and lives in small groups occupying the same territory away from human habitations [7].

Parasitism is affected by complex interactions between host, parasite, and their shared environment. Host behavior may also be a risk factor for parasites [8].

The intensity of ectoparasite infestations may increase with an increase in the density of host populations [9]. In addition, the abundance of ectoparasites is highly dependent on the abundance of rodents and available host communities [10]. Parasite infestations are also dependent on the host gender differences [11].

Ectoparasites may have a negative impact on hosts by reducing survival, fertility, and growth [12]. Some ectoparasites can even synchronize their reproductive cycle to access the most profitable individuals, host populations, or use propagation

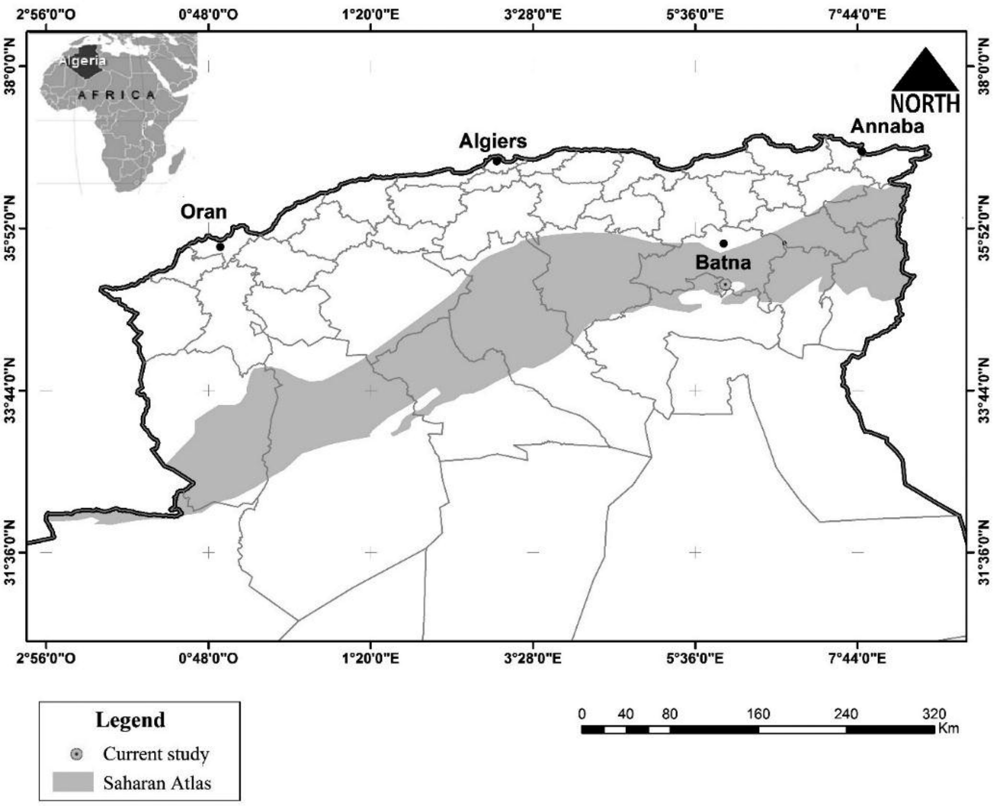

Figure 1. Study area

strategies to increase their chances of finding new hosts [13]. In this regard, host-ectoparasite associations provide useful data to understand the associated epidemiological risks. Host characteristics such as gender, body size, ecology, and social systems can affect the diversity of ectoparasites [14].

Several studies documenting the host-parasite relationships of fleas and the gundi are those of [15–18]. None of these studies addressed statistical analyses of host sex, environmental, climatic conditions, or effects on the gundi populations.

The objectives of our study is to determine the diversity and density of ectoparasites species of the gundi from the eastern region of Algeria, while developing their specificity concerning sex, age of the host, and the climatic conditions such as temperature, wind, and humidity that may influence their abundance. Ectoparasite studies of the gundi have not been conducted previously in Algeria, or elsewhere.

Materials and Methods

Study area

The Aures region 34°48’ to 35°29’N; 6°07’ to 7°06’E (Fig. 1) is part of the Saharan Atlas Mountain range located about 50 km south of the capital Algiers. The region is characterized by a semi-arid climate with temperatures varying between 2°C (January) and 26°C (July) and irregular rainfall of 210 mm/year. Samples of ectoparasites were taken from 74 gundi captured at two sites (S1 and S2).

These two sites are located at the south of this massif (S1: 35°08’59.51’’N, 5°59’22.11’’E, 851 m; S2: 35°08’49.39’’N, 5°55’30.22’’E, 922 m) Dominate vegetation included. *Juniperus communis* with some *Ziziphus spina-christi* and sub-dominate low growing vegetation of *Artemisia herba-alba*, *Rosmarinus officinalis*, and *Ampelodesmos mauritanica*.

Capture of common gundi

The gundi was captured from December 2015 to June 2017 once each month at each site. Individual gundi’s were captured manually according to the protocol developed by [19].

All animals were captured alive which was beneficial in maximizing the true yield of ectoparasites. Locality data, date of capture, sex, weight, and body measurements were recorded for all individuals. Age classes were estimated from dental wear [20,21].

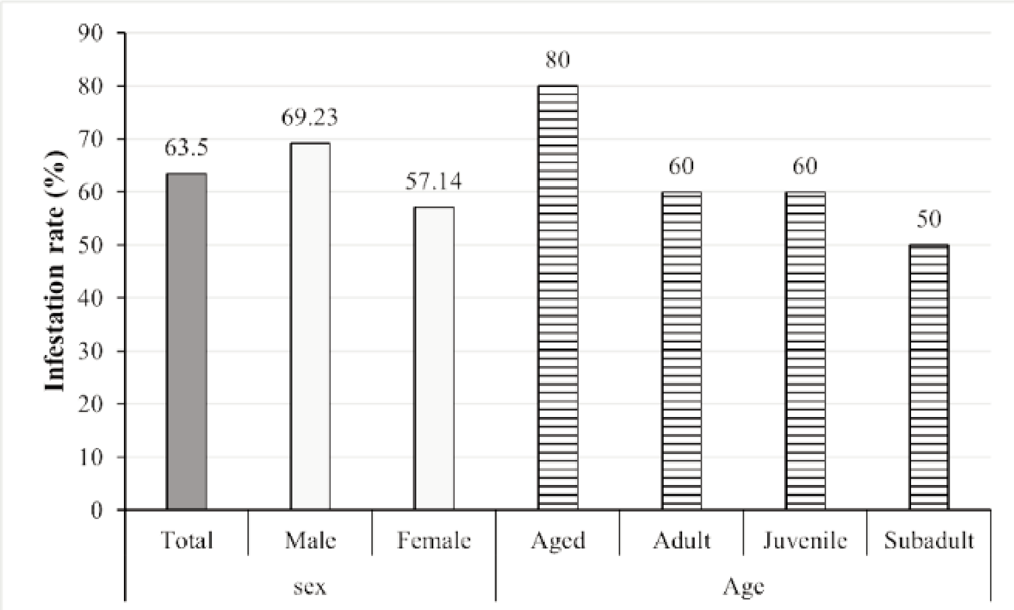

Figure 2. Infestation rate of *C. gundi* captured by sex and by age class in the study area

Collection of ectoparasites

Individual animals were anesthetized by placing in a plastic bag with a piece of chloroform-soaked cotton wool. Ectoparasites were extracted from each host with forceps and a moistened camel hair brush. Ectoparasites from individual hosts were stored in 70% ethanol, one vial per host. Fleas, lice, and mites were processed and mounted in accordance with procedures outlined in [22]. Mites were identified in accordance with [23,24]; fleas with [25,26]; lice with [27], and ticks with [28–31].

Data analyses

The abundance of captured individuals was calculated for gundi and ectoparasites. Descriptive statistics were calculated for ectoparasites to determine their infestation rate by sex and age of the host. We considered that a rodent was infected if at least one individual ectoparasite was noted. Parasitological parameters (relative density, mean intensity, and prevalence) are defined as follows:

Relative density (RD): the calculation formula was established as follows [32]: RD% = (Np/N) where: RD% = relative density (abundance), Np = total number of a particular parasite species in a sample of the host, N = total number of individuals of hosts species (infected and uninfected) in the sample;

Mean intensity (MI): according to [33], the calculation formula is as follows: MI = Np/Nip where: MI = mean intensity, Np = total number of a particular parasite species in a sample of the host, Nip = total number of individuals of the hosts infected with that parasite;

Prevalence (P): the calculation formula was established as follows [33]: P (%) = (Nih/N) × 100 where: P = prevalence, Nih = total number of rodent hosts infected with a particular parasite species, N = total number of individuals of hosts species (infected and uninfected) in the sample.

The comparison of the various parasitological parameters was carried out by the use of statistical tests, in particular, Kruskal-Wallis test for the abundance and spectrum of gundi ectoparasites. The regression for the relationship between ectoparasites abundance and climate. The data is processed using Statistica software (Version 12).

Results

Common gundi abundance and infestation rate

A total of 74 gundi were captured in the Aures region. Males were the most captured (52.7%) compared to females (47.3%) with a non-significant difference (P=0.9570) between the two sexes. The numbers of gundi captured were represented by four age categories. The class of adults was the largest (71.6%). It was followed by old individuals with a rate equal to 13.5%, while juveniles (6.8%) and subadults (8.1%) were the least captured. The test of Kruskal-Wallis revealed that there was a significant difference (P=0.0393) between the different age categories.

More than half (63.5%) of the individuals were infested with at least one ectoparasite (Fig. 2). Males were infested more frequently (69.2%) than

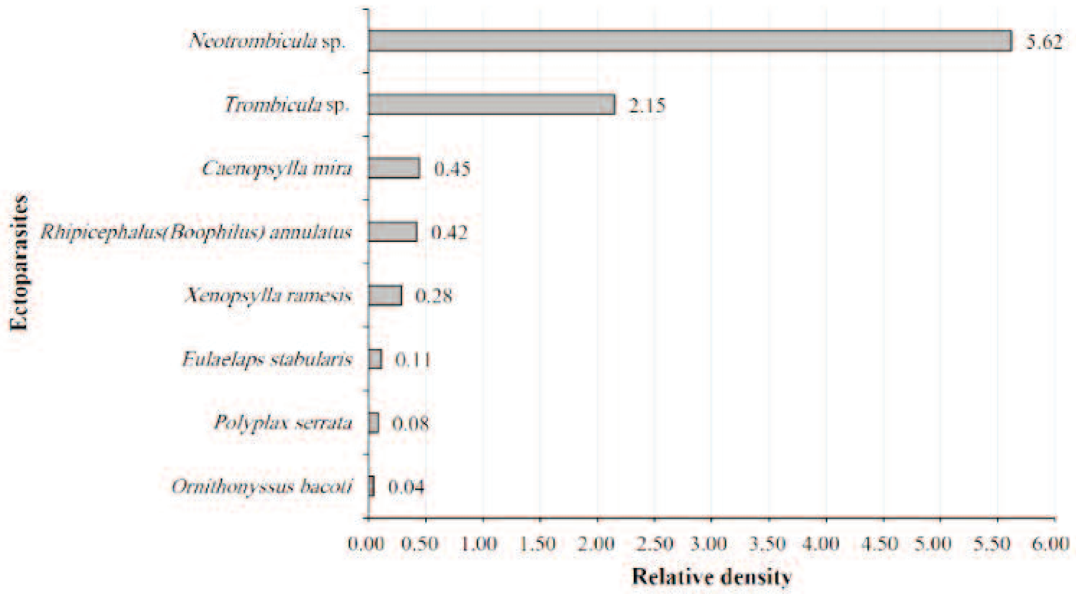

Figure 3. Relative density of ectoparasite of the gundi

females (57.1%). Old individuals were most frequently infested, while subadults were the least infested.

Relative density of parasites

A total of 677 ectoparasites were isolated from *C. gundi*. They included fleas *C. mira* (n=33) and *X. ramesis* (n=21); lice *P. serrata* (n=6); tick *Rh.* (*Boophilus*) *annulatus* (n=31); and mites *O. bacoti* (n=3), *E. stabularis* (n=8), *Trombicula* sp. (n=159) and *Neotrombicula* sp. (n=416).

The relative density was greatest among the trombidiformes: *Neotrombicula* sp. (5.62) and *Trombicula* sp. (2.15) (Fig. 3) followed by fleas represented by *C. mira* (0.45) and ticks represented by *Rh.* (*Boophilus*) *annulatus* (0.42). Anopluran lice and mesostigmatid mites were scarcely found (Fig. 3).

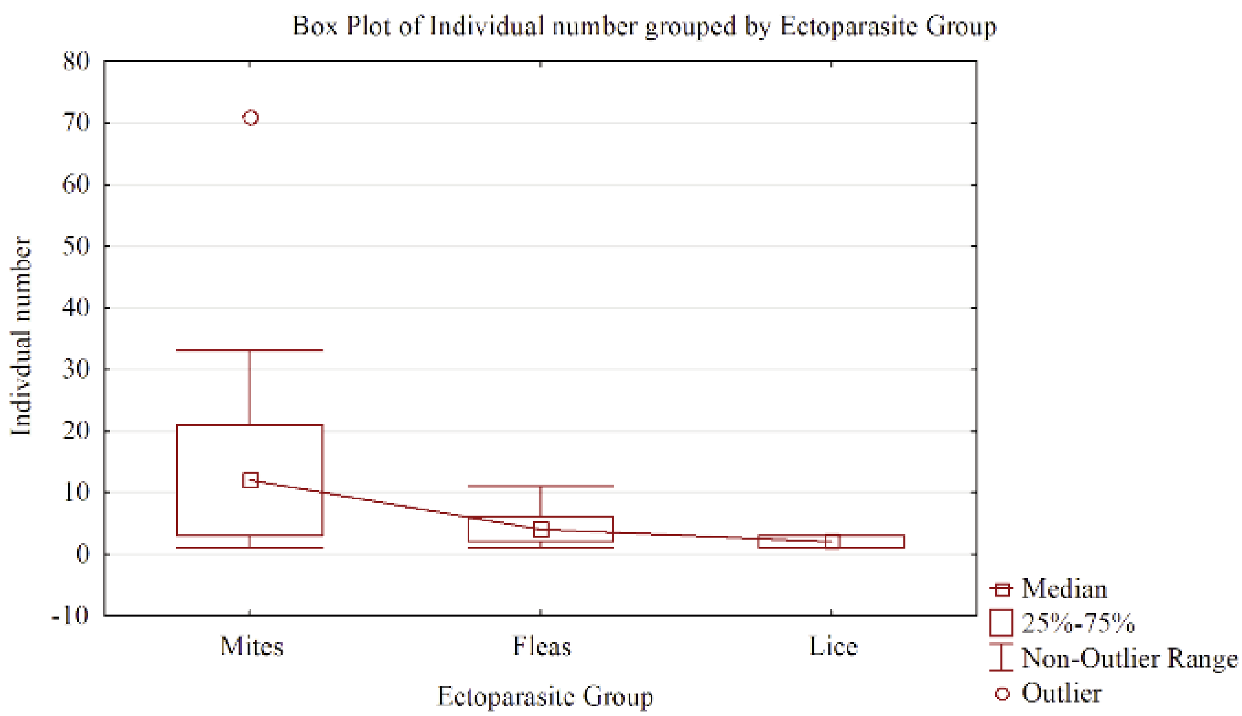

Figure 4. Spectrum of parasitism in common gundi in the Aures region

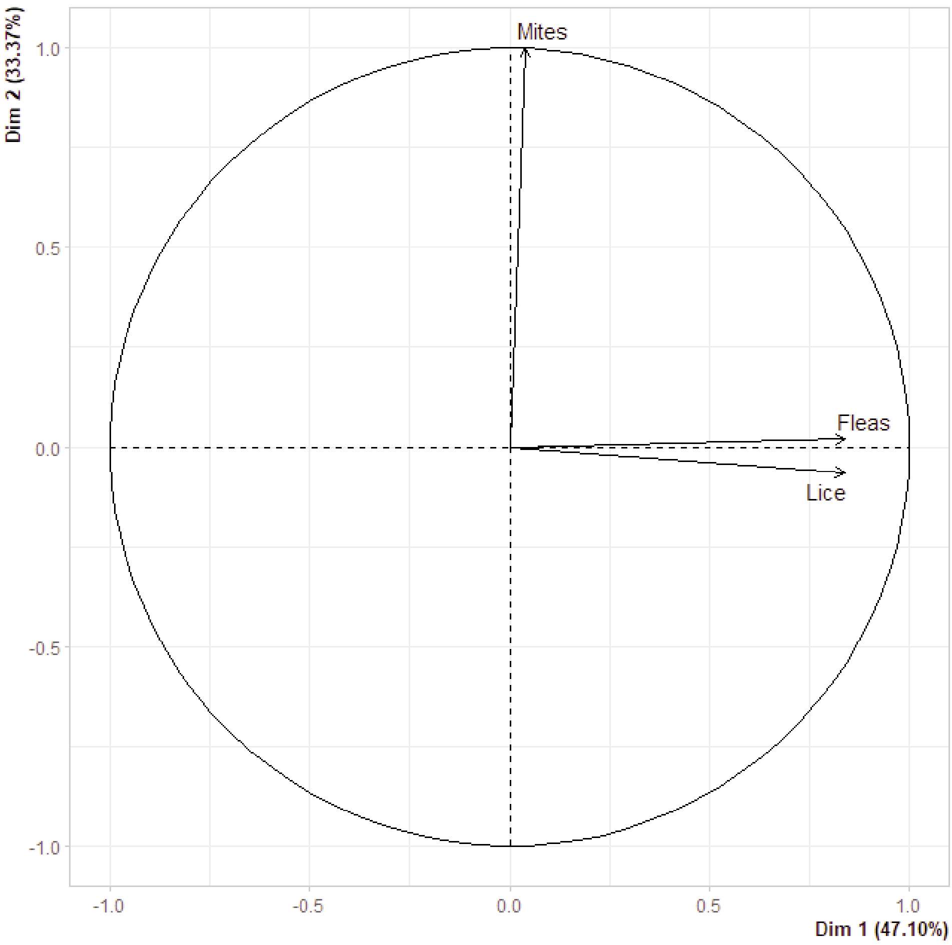

Figure 5. Correlation circle of the gundi ectoparasites

Common gundi ectoparasite spectrum

Overall, more than 1/3 individuals of *C. gundi* are not infested with ectoparasites (36.5%). Mites are most abundant in this rodent (91.1%) followed by fleas (8.0%), and lice (0.9%). The Kruskal-Wallis test showed that there was a highly significant difference (KW-H (2; 60)=10.7504; *P*=0.0046) between the different groups of gundi ectoparasites. Each gundi individual harbored between 1 and 34 mites (mean=14.0±9.4; Fig. 4) followed by fleas (mean=4.2±2.3) and lice (mean=2±0.7).

Multiple correspondence analysis applied to gundi ectoparasites

The circle of correlations shows that fleas and lice are inversely proportional on axis 1, on the other hand mites are distributed independently on the gundi compared to the other two groups of ectoparasites (Fig. 5). The factorial map of individuals shows that age has an influence on the distribution of ectoparasites along axis 2, which is strongly conditioned by mites (Fig. 6). On the other hand, sex has no influence on this distribution, because the two sexes are side by side near the origin of the axes.

Mean intensity of ectoparasites from the common gundi

The collection of ectoparasites demonstrated a higher mean intensity for *Neotrombicula* sp. (14.3) and *Trombicula* sp. (10.6) (Fig. 7). While the weakest were represented by *O. bacoti* (1) and *E. stabularis* (1.6).

Depending on host gender, the same was noted with a medium-high intensity of *Neotrombicula* sp. (♂: 15.3; ♀: 13.4) and *Trombicula* sp. (♂: 12.8; ♀: 7.3) in both host sexes (Fig. 7). The lowest values were recorded for *O. bacoti* (1) in males and *Rh.* (*Boophilus*) *annulatus* (1.3) for females.

Prevalence of common gundi parasites in the study area

Nearly all of these arthropods have a higher

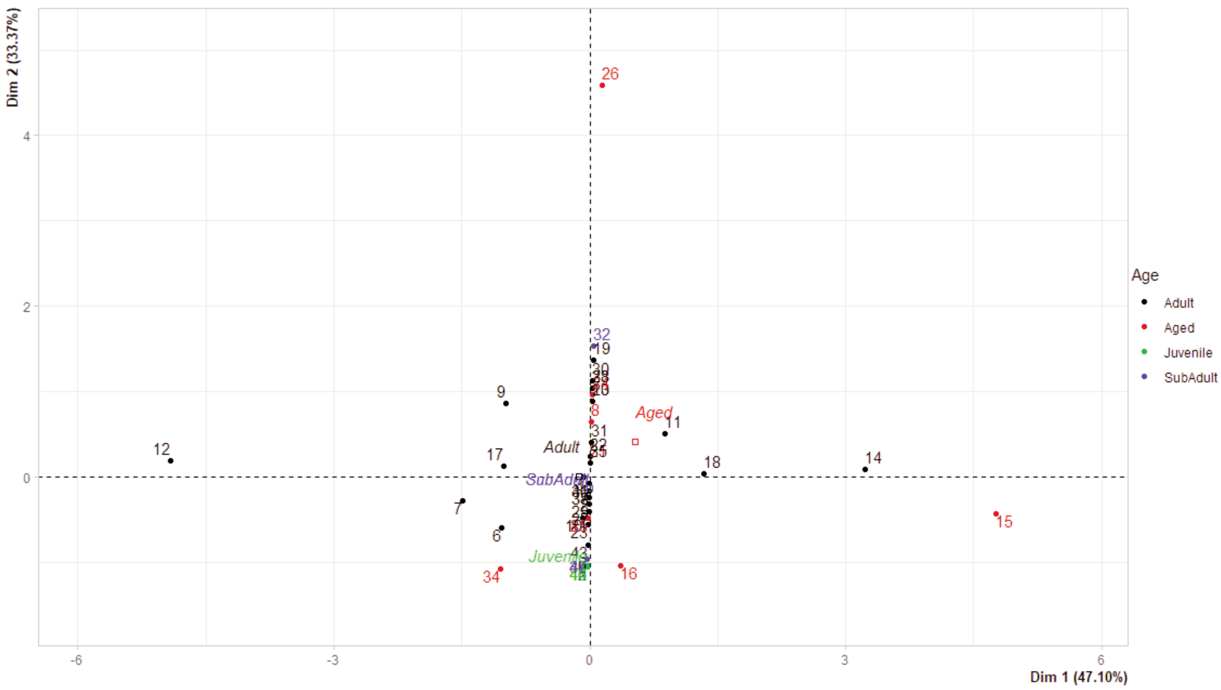

Figure 6. Factorial map of the gundi ectoparasites

prevalence in males (P=79.5%) than females (P=62.9 %; Fig. 8); however, the ectoparasite species *Neotrombicula* sp. (♀: 40% > ♂: 38.5%), *C. mira* (♀: 14.3% > ♂: 12.9%) and *X. ramesis* (♀: 11.4% > ♂: 5.1%) present a higher prevalence in females than males (Fig. 8).

Influence of climatic conditions on the abundance of ectoparasites

The variation in the number of ectoparasites per individual animal was directly related to the climatic conditions (Fig. 9). Temperatures have a negative correlation with the number of parasitized individuals (y=13.6073 – 0.2069 *x; r = –0.5150; *P*=0.0002, r^2=0.2653). It was the same for wind (y=12.9528 – 0.0368 *x; r =-0.2430; *P*=0.0997, r^2=0.0591), while humidity was positively correlated with ectoparasites of the gundi (y=58.4072+0.3867 *x; r=0.4517; *P*=0.0014, r^2=0.2041).

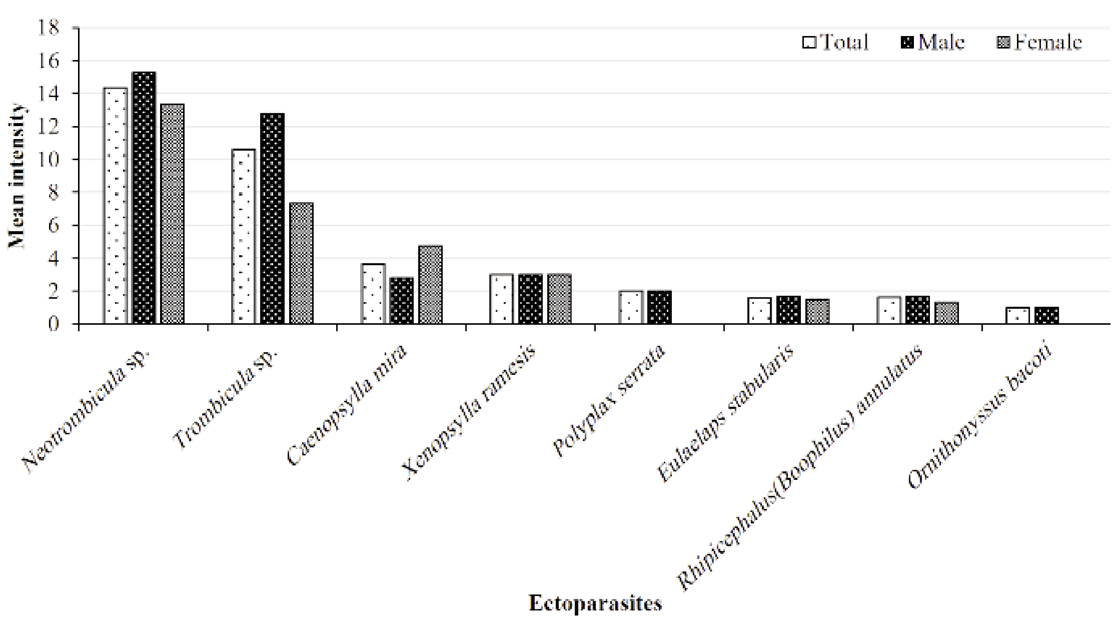

Figure 7. Mean intensity of ectoparasites from the gundi in the Aures region

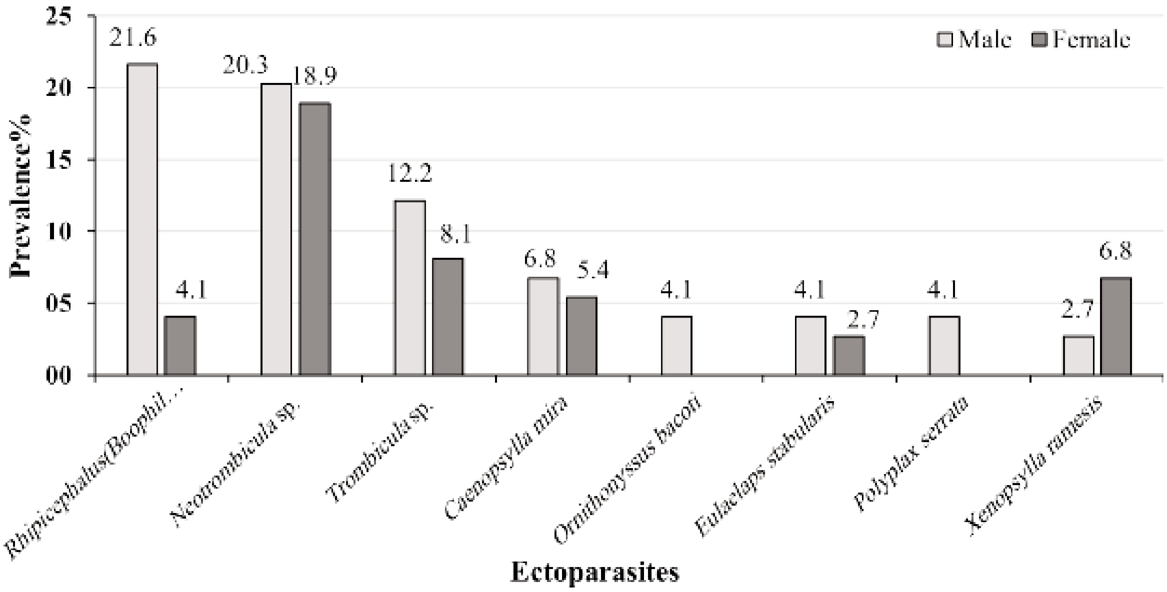

Figure 8. Prevalence of the gundi ectoparasites by sex in the study area

Discussion

Common gundi abundance and infestation rate

The rate of parasitism in the gundi of the Aures was relatively high (63.5%), with an increase in males (69.2%) compared to females (57.1%). In addition, aged individuals (80%) were the most infested because they were often weak, with limited mobility which subjects them to more time in the nest where the environmental parameters are most suitable for ectoparasites. The chief causes of rodent infestation by ectoparasites were often represented by factors associated with the host such as density, dynamics, and sex, and/or environmental factors such as humidity and temperature [34].

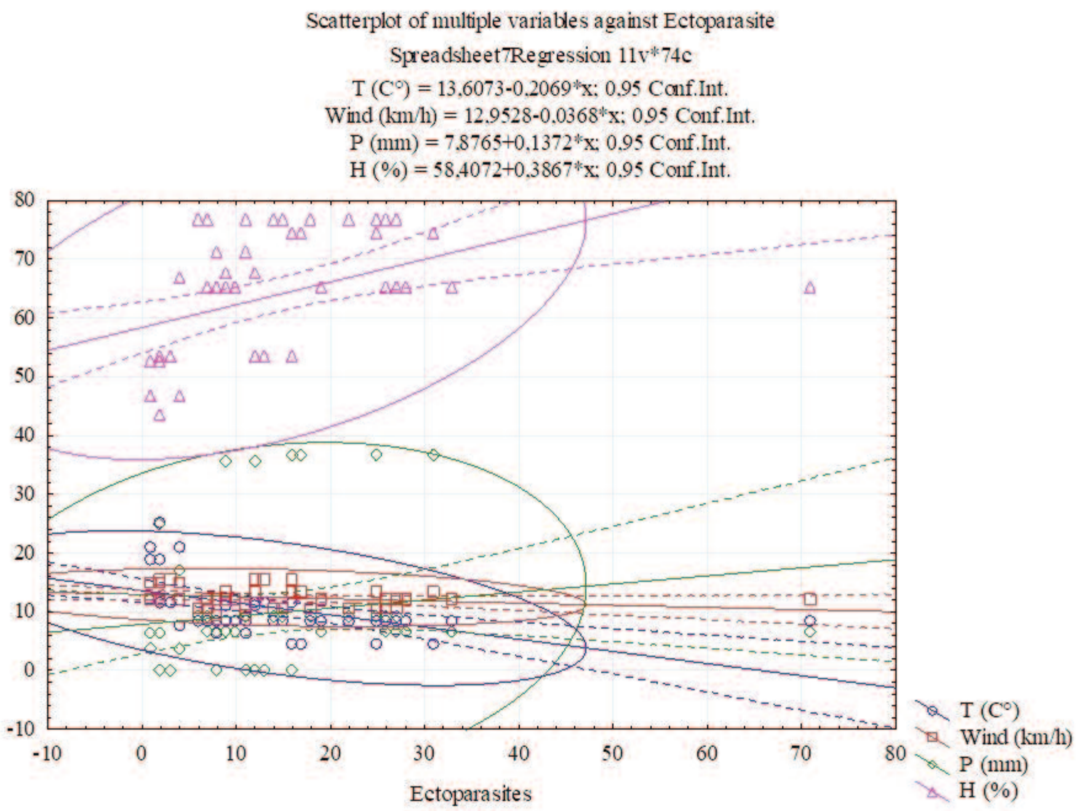

Figure 9. Influence of climatic conditions on the number of individual ectoparasites

Relative density, prevalence, and mean intensity of parasites

Ectoparasites sampled in this study include mites (91.1%), fleas (8.0%), and lice (0.9%). *Neotrombicula* sp. is the most abundant (5.62) followed by *Trombicula* sp. (2.15) and *C. mira* (0.45). The mean intensity of *Neotrombicula* sp. (14.3) and *Trombicula* sp. (10.6) is higher than that of *O. bacoti* (1.0) and *E. stabularis* (1.6) which is relatively much lower.

These ectoparasites have a high prevalence on male hosts (79.5%) compared to female hosts (62.9%). *Neotrombicula* sp. (39.2%) and *Rhipicephalus* (*Boophilus*) *annulatus* (25.7%) have the highest values followed by *Trombicula* sp. (20.3%) and *C. mira* (12.2%).

Stekolnikov [35] reported that *Neotrombicula* larvae are specific to vertebrates, such as rodents and lagomorphs. Some species such as *Neotrombicula autumnalis* have been isolated from several rodents such as *Peromyscus maniculatus* Wagner (Rodentia, Cricetidae) with a prevalence of 24.9, *Myodes gapperi* Vigors (Rodentia, Cricetidae) with 85.7. Species of *Polyplax* are ectoparasites common to Abrocomidae, Cricetidae, Muridae, Nesomyidae, Spalacidae, Sciuridae and Soricidae, while *P. serrata* is specific to Murinae such as *Apodemus* Kaup (Rodentia, Muridae) and *Mus* Linn. (Rodentia, Muridae) [36,37].

The dearth of *P. serrata* is more likely due to host-related factors. *P. serrata*, and its congener (*P. spinulosa*) are closely related with very similar morphology [38]. Sucking lice are highly host-specific compared to other ectoparasites such as certain chewing lice and most mites, ticks, fleas [39,40]. A small proportion of lice species parasitize two or more host species [36,41].

Many small mammal species share the same ecological niches as the gundi to include: rodents (*Hystrix cristata* Linn. (Rodentia, Hystricidae), *Gerbillus campestris* Levaillant (Rodentia, Muridae), *Psammomys obesus* Cretzschmar (Rodentia, Muridae) and insectivores (*Atelerix algirus* Lereboullet (Erinaceomorpha, Erinaceidae) and *Elephantulus rozeti* Duvernoy (Macroscelidea, Macroscelididae)) [7]. The presence of some species first reported in this study (*Neotrombicula* sp., *Trombicula* sp., *Rh.* (*Boophilus*) *annulatus, E. stabularis*, *P. serrata, O. bacoti*) on the gundi may be justified by niche sharing, particularly with *A. algirus* which is often infested with *R. sanguineus* [42]. *C. mira* was collected from *E. rozeti* in Tunisia [43] and *R. bursa* was found on *H. cristata* [44]. The genus *Gerbillus* is an important host of *X. ramesis* in the Morocco region [16].

O. bacoti is reported on gundi for the first time while it has been reported many times on rats (*Rattus norvegicus* Berkenhout (Rodentia, Muridae) and *R. rattus* Linn. (Rodentia, Muridae)) [45].

C. mira occurs almost exlusively on *C. gundi* in the coastal region of North Africa (Algeria, Libya, Morocco, and Tunisia) [15–18]. [15] attributed a host association with *Eliomys munbyanus* Pomel (Rodentia, Gliridae) as accidental. *Eliomys* occupies a similar ecological niche with that of *C. gundi*. [16] also reported *X. ramesis* on *C. gundi* in Morocco.

Transmission of diseases by ectoparasites (mites, fleas, and lice) has been proven by multiple authors [46]. DNA of *Bartonella tribocorum* a known human pathogen [47] was detected in *P. serrata* collected from *A. agrarius* [37], while transmission by *P. serrata* has not been demonstrated. [48] considered *O. bacoti* a potential vector of cat scratch fever (*B. henselae*) but transmission has not been proven. Horizontal transmission of some pathogens such as *Rickettsia* sp. via a blood meal occurs in some ectoparasites [49].

Influence of climatic conditions on the abundance of ectoparasites

The present study shows that the variation in ectoparasite numbers is directly related to climatic conditions, including temperature and rainfall. Temperature and rainfall are negatively correlated with ectoparasite abundance; however, humidity has a positive correlation. Carrillo et al. [34] and Amat-Valero et al. [50] have studied the influence of temperature, wind, and air humidity on the abundance and distribution of ectoparasites around the world. Ectoparasites are subject to pronounced microclimatic fluctuations more that free-living arthropods. Air temperature and humidity can affect the juvenile stages of fleas and mites resulting in variation in survival and development time [12,51]. The prevalence and abundance of mites are higher during warm seasons [10]. Mites survive better and develop more rapidly at higher ambient temperatures [12]. According to [52], precipitation had a positive effect on mites, while [10] reported negative effects of precipitation in both mites and fleas.

The study of ectoparasites of *C. gundi* in the Aures region noted the presence of fleas, mites, lice, and ticks. Some species are specific to Gundi, such as *C. mira*, while *P. serrata*, *B. annulatus*, *O. bacoti*, *E. stabularis*, *Trombicula* sp. and *Neotrombicula* sp. are documented for the first time. These have a wide range of small mammals and bird hosts.

The abundance of these ectoparasites is closely related to the sex and age of *C. gundi* and climatic conditions. Results of this study suggest further investigations into the potential vector capacity of these ectoparasites for the notable agents *Bartonella* and *Rickettsia* [46].

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