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Parasitic Infestation Patterns of Water Mites (*Arrenurus spp.*) on Odonata Species in North African Freshwater Habitats

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ABSTRACT

This study investigates the parasitic relationship between water mites and Odonata species in a lotic environment in Souk Ahras, analyzing 27 species including both Zygoptera and Anisoptera. Over a two-year period, we recorded 744 parasitic larvae on 110 individuals belonging to four Zygoptera species: *Platycnemis subdilatata* (Selys, 1849), *Coenagrion caerulescens* (Fonscolombe, 1838), *Coenagrion mercuriale* (Charpentier, 1840), and *Ischnura graellsii* (Rambur, 1842). Generalized linear model revealed significant differences in infestation levels based on species and body parts, while sex differences were not significant. *P. subdilatata* exhibited the highest infestation rate of 2.74%, accounting for 75 infested individuals. In contrast, *C. caerulescens*, *C. mercuriale*, and *I. graellsii* showed lower prevalence rates of 1.28%, 1.01%, and 0.95%, respectively. Mites were predominantly found attached to the thorax, probably because it provides better survival chances and more favorable conditions for larval development. Our findings highlight a strong host preference by water mites, indicating that only certain damselflies serve as hosts, thus contributing to the understanding of parasitism dynamics in freshwater ecosystems.

Keywords: Odonates, Lotic environment, Souk Ahras, Parasitic larvae, Infestation, Damselflies.

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INTRODUCTION

Host-symbiont interactions are fundamental ecological relationships that shape biodiversity and ecosystem dynamics. These interactions exist along a continuum, ranging from mutualism, where both organisms benefit, to parasitism, where one organism benefits at the expense of the other (Newman, Gillis, & Hager, 2021). Although viewed negatively, parasites can benefit other species, influence food web complexity, and affect community composition. They also contribute to ecosystem energy budgets thus underscoring their importance for conservation and public health (Hatcher, Dick, & Dunn, 2012). In freshwater ecosystems, parasitic interactions involving aquatic insects, particularly Odonata, provide notable examples of these ecological dynamics. The Odonata not only fulfill crucial ecological functions but also serve as valuable bioindicators of environmental health (Miguel, Oliveira-Junior, Ligeiro, & Juen, 2017). Their prominence in scientific literature contrasts with that of other important aquatic insect groups, such as Coleoptera, Ephemeroptera, Plecoptera, and Trichoptera, which are often underrepresented (Kohler, 2008). This underscores the significant focus on Odonata in understanding host-parasite dynamics and their implications for the health of freshwater ecosystems.

Odonates are primarily ectoparasitized by Ceratopogonidae, such as *Forcipomyia paludis* (Martens et al., 2008), and water mites (Hydrachnidia), particularly from the families Hydryphantidae and Limnocharidae, during the imago stage. In contrast, Arrenuridae generally parasitize odonate immature stages (Smith & Oliver, 1986). These parasites depend on odonates for both nutritional resources and habitat throughout their life cycles (Andrew, Thaokar, & Verma, 2012). Specifically, water mites use odonates as hosts to feed on their haemolymph and to achieve sexual maturation during the adult (imago) stage of the host (Forbes & Robb, 2008).

Water mites (Hydrachnidia) constitute a significant group within class Arachnida, with over 6,000 species described worldwide (Cook, 1974; Viets, 1987). The attachment body part of these larval mites on a host varies according to the host's morphology and the mite's phylogenetic background (Smith & Oliver, 1986; Smith, Cook, & Smith, 2001). This parasitic interaction can have significant effects on the host, thus affecting its health, behavior, and ecological roles, reducing body mass (Smith, 1988), causing tissue damage (Åbro, 1982), affecting developmental stability, and hindering fertility by obstructing sperm transfer to the male's secondary genitalia or interfering with copulation (Bonn, Gasse, Rolff, & Martens, 1996; Forbes, 1991; Forbes & Baker, 1991). In response, odonates can aggregate hemocytes at the punctured body part and produce melanotic encapsulations around the feeding tubes, immobilizing the mites, which become "deflated" (Nagel, Mlynarek, & Forbes, 2011). This response serves as a visible indicator of host resistance. The capacity of Odonates to resist parasitism and the difference in parasitism rate even between congeneric species (Worthen & Hart, 2016) highlight the complex interplay between ecological factors, such as the abundant host species and possible evolutionary adaptations in response to parasitism (Hasik, Ilvonen, Siepielski, & Murray, 2022). Larval water mites of the

Arrenurus genus actively seek their hosts during their larval stage (Ilvonen, 2018), timing their peak host-seeking activity to coincide with the emergence of preferred odonate hosts from the water (Michell, 1967; Smith, 1988). Upon locating a larval odonate, the water mite attaches itself and remains in place until the host emerges as an adult.

Once the odonate reaches maturity, the mite transfers from the larval exoskeleton, to the skin of the newly emerged adult (Mitchell, 1961). Individual Odonates can host over 400 mites simultaneously (Worthen & Turner, 2015), with mite infestation prevalence reaching 100% for certain species in specific habitats (Zawal & Buczyński, 2013). Several studies have demonstrated that ectoparasitism of Odonata species varies significantly, with some species showing greater susceptibility to infestation (Ilvonen, 2018) due to factors such as morphological and life history traits (Bunker et al., 2013), as well as environmental conditions like vegetation biomass and climatic stability (Da Silva, Poulin, & Guillermo-Ferreira, 2021).

To date, only one study has been conducted in North Africa that specifically addressing the parasitism of Odonata, with a focus on *Forcipomyia paludis* as a parasite (Boudot, Havelka, & Martens, 2019). Moreover, despite strong interest in odonate studies in Algeria, most research has focused on their taxonomic distribution (Samraoui & Corbet, 2000; Chelli & Moulai, 2019; Chelli, Moulai, & Djemai, 2020; Ait Taleb, Ali Ahmed Sadoudi, Bensidhoum, & Houhamdi, 2024), reproduction and life cycles (Samraoui, Bouzid, Boulahbal, & Corbet, 1998; Mellal, Bensouilah, Houhamdi, & Khelifa, 2018; Samraoui, Touati, & Samraoui, 2019), and responses to climate change and anthropogenic pressure (Hafiane et al., 2016; Khelifa, Mahdjoub, Baaloudj, Cannings, & Samways, 2021). Consequently, the parasitological aspects of these insects remain notably understudied, particularly in regions like North Africa. This gap in knowledge restricts our understanding of host-parasite interactions within freshwater ecosystems. Addressing this issue will enhance our understanding of the ecological roles of Odonates and their responses to environmental changes. This study aims to explore the prevalence, distribution, and infestation patterns of water mites (*Arrenurus* sp.) infestation in odonata species inhabiting the freshwater ecosystems of Souk Ahras (Algeria). Specifically, it aims to identify the Odonata species most affected by water mite parasitism, investigate differences in infestation patterns across various body parts (thorax, abdomen, wings), and assess potential differences in parasitism rates between male and female hosts. Furthermore, this research establishes a foundation for future investigations into the phenology and environmental factors influencing infestation rates.

MATERIALS AND METHODS

Study area and Sampling Method

Between January 2022 and August 2023, adult odonates were collected monthly from a lotic ecosystem in Souk Ahras, at eight sampling stations located at elevations ranging from 598 to 818 meters asl (Fig. 1). All odonate species observed within and around the water body, along a 100-meter transect, were recorded and identified using the field guide by Dijkstra & Lewington (2007). Mite larvae attached to each specimen were carefully removed using fine histological tweezers and needles, then preserved in Eppendorf tubes containing Koenik's fluid (40 mL distilled water, 10 acetic acid, and 50 glycerin). After mite removal, the sampled individuals were released, and their subsequent flight was carefully monitored to ensure minimal harm.

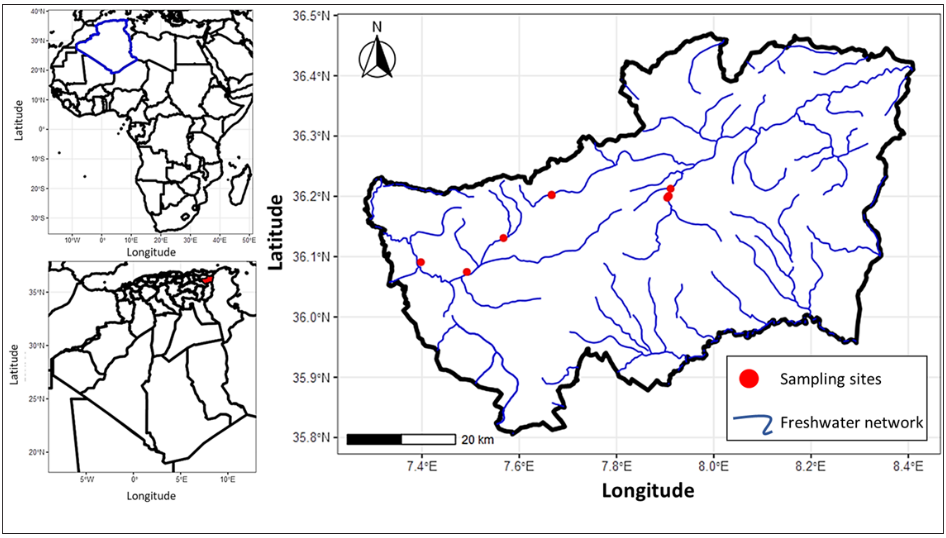

Figure 1. Study area location.

Data Analysis

The prevalence of infestation was calculated as the proportion of parasitized individuals relative to the total number of individuals analyzed (parasitized individuals/ total individuals analyzed × 100). In addition, to determine whether mite counts varied by species, sex, or body part, a generalized linear model (GLM) with a negative binomial distribution and a log link function was performed using the *glm.nb* function from the MASS package (Ripley et al., 2013) to account for overdispersion. Afterwards, post hoc analysis for category differences was performed using the *glht* function from the multcomp package (Hothorn et al., 2016).

RESULTS

Over the two-years period, a total of 27 species, belonging to 7 families were analyzed, 744 parasitic larvae of water mites were found on 110 (♀ and ♂) specimens representing four species of Odonata from the suborder Zygoptera. Our results showed that, *P. subdilatata* was the most infested species, with 75 individuals observed carrying larval water mites on their bodies (Fig. 2). This species exhibited the highest prevalence among those infested, at 2.74%. The second most infested species was *C. caerulescens,* which was recorded with 13 infested individuals and a prevalence rate of 1.28%. Lastly, *C. mercuriale* and *I. graellsii* had the lowest prevalence with, 1.01% and 0.95%, respectively. Only 11 parasitized individuals of each species were encountered during the survey (Table 1).

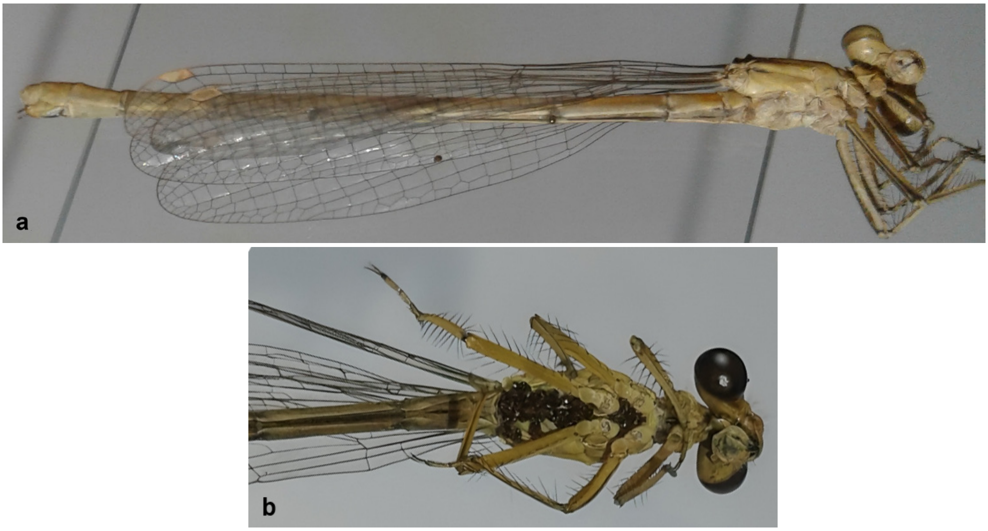

Figure 2. Presence of aquatic mites (*Arrenurus*) on different body parts of *Platycnemis subdilatata,* a) abdomen and wings, b) thorax.

Table 1. Details of mite-Infested Odonates: Prevalence, sex distribution, and body localization of Infestation (numbers indicate mites per body part).

Odonata species	Parasitized individuals	Prevalence of infestation (%)	Part of host's body			Specimens parasitized by sex	
			Abdomen	Thorax	Wings	♀	♂
Platycnemis subdilatata	75	2.74	17	657	3	41	34
Coenagrion mercuriale	11	1.01	1	11	1	4	7
Coenagrion caerulescens	13	1.28	2	21	1	8	5
Ischnura graellsii	11	0.95	2	28	0	5	6

Mite counts were significantly influenced (Table 2) by odonate species and body part, whereas differences between sexes were not significant.

Table 2. Results of generalized linear model (GLM) with negative binomial error distribution to compare parasite abundance among Odonate species, body part, and sex.

	Df	**Sum Sq**	**F value**	**P-value**
(Intercept)		-2.67	-6.35	<0.001 ***
Species	3	25.55	4.02	<0.001 ***
Body part	2	420.26	99.19	<0.001 ***
Sex	1	0.34	0.16	0.56

In the four odonate species infested with mite, mite abundance differed significantly between *P. subdilatata* and the other three species. Specifically, *P. subdilatata* exhibited significantly higher mite abundance compared to *C. caerulescens* (Estimate = 1.3489, Z = 3.801, $p < 0.001$), *C. mercuriale* (Estimate = 1.4936, Z = 3.776, p = 0.00103), and *I. graellsii* (Estimate = 1.0356, Z = 2.837, p = 0.02265). However, there were no significant differences in mite abundance among *C. caerulescens, C. mercuriale,* and

I. graellsii ($p > 0.05$) (Fig. 3). Mite abundance also varied significantly across different body parts (Fig. 4). Mite abundance on the thorax was significantly higher than on the abdomen (Estimate = 3.45, Z = 12.83, $p < 0.001$), while the wings had significantly fewer mites compared to both the abdomen (Estimate = -1.2560, Z = -2.594, p = 0.024) and the thorax (Estimate = -4.7114, Z = -10.83, $p < 0.001$).

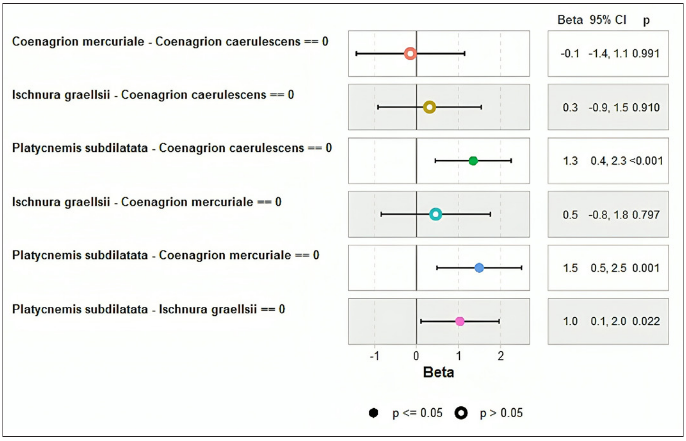

Figure 3. Multiple Comparison of odonate species in terms of mite count. Confidence Intervals not crossing zero on the x-axis Indicate a significant difference.

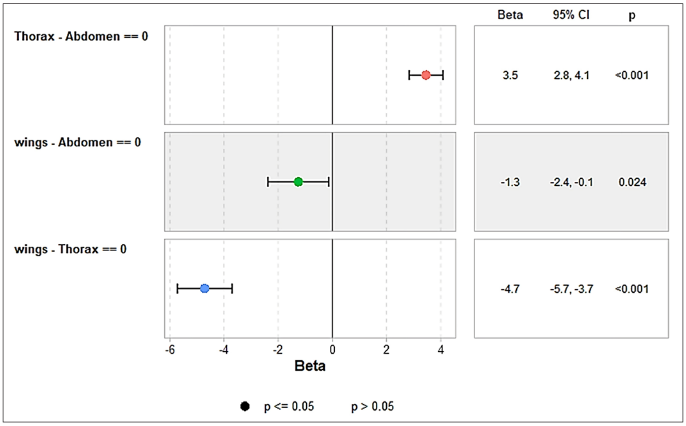

Figure 4. Multiple Comparison of body parts in terms of mite count. Confidence Intervals not crossing zero on the x-axis Indicate a significant difference.

DISCUSSION

Literature indicates a strong taxonomic preference of Arrenurid mites for parasitizing Diptera and Odonata (Rolff, 2001), with the genus *Arrenurus* being specialized in parasitizing odonata (Smith, 1988). This paper provides new insights into odonata hosts of parasitic larvae from the *Arrenurus* genus in lotic environments of Northern Africa, where no data had previously been reported for four damselfly species (*P. subdilatata*, *C.*

caerulescens, *C. mercuriale*, and *I. graellsii*). In general, our results agree with other studies, which show that zygopterans are more frequently infected than anisopterans (Conroy & Kuhn, 1977; Davids, 1997; Zawal, 2004; 2006; Ilvonen, 2018; Janra & Herwina, 2021).

The fact that parasitism was found only in damselflies and not in dragonflies is likely linked to the longer larval period of dragonflies compared to that of damselflies, as well as their lower population density (Rivas-Torres & Cordero-Rivera, 2024), which increases the opportunity for mites to find their hosts. Additionally, damselflies are generally found living around water bodies for most of their lives, which increases the likelihood that water mites can return to water as soon as their parasitic phase ends. Among zygopterans, we recorded interspecific variation in water mite infestation, with prevalence ranging from 0.95% in *Ischnura graellsii* to 2.74% in *Platycnemis subdilatata*, which also had the highest number of infested individuals (75). Although infestation levels were generally low across species, *P. subdilatata* showed the greatest recorded prevalence, albeit only slightly higher compared to other species. Possibly affected by the sheer abundance of the latter species in the study area, this may be due to specific biological factors. However, this result should be interpreted with caution, as the sample size is not large enough to draw definitive conclusions. Further research is necessary to determine whether these parasitic preference patterns hold with larger sample sizes.

Water mite parasitism is influenced by both environmental factors (e.g., dissolved oxygen, conductivity, pH, and air temperature) and host traits (e.g. body mass) (LoScerbo, Farrell, Arrowsmith, Mlynarek, & Lessard, 2020; da Silva et al., 2021; Hasik & Siepielski, 2022). In the water mite literature, numerous reports evaluate the differential parasitism of host sexes. Robb & Forbes (2006); Zawal (2004, 2006); Zawal & Dyatlova (2008); Baker, Mill, & Zawal (2008); Andrew et al. (2012) and Janra & Herwina (2021) have indicated clear preferences for the infestation of female hosts. This preference has also been observed in *Ceriagrion tenellum* (Andrés & Cordero, 1998). Female odonates oviposit in or near water,which increases their exposure to aquatic environments and, consequently, to water mites. Alternatively, specific behaviors exhibited by female odonate, such as their habitat preferences or activity patterns, may also increase their susceptibility to mite infestations. Therefore, attachment to female odonates could be advantageous for larval water mites to complete their life cycle.

However, this biased sexual imbalance was not confirmed in the present study, likely due to the low infestation rate, which may have limited the statistical power to detect such differences. Likewise, Rolff (2000); Zawal & Buczyński (2013); Ilvonen, Kaunisto, & Suhonen (2016) reported the absence of such differences. This is because mites attach to their hosts while immature, without considering the sexual differences that appear later (Ilvonen et al., 2016). Paul, Khan, & Herberstein (2022) proposed that sex-related disparities in infestation rates across species might stem from unique differences in body condition, shaped by both sexual and developmental factors. However, the results obtained did not provide clear answers, and analyzing a large dataset from various environments is essential to determine whether parasites exhibit a preference for the sex of their hosts.

Our data clearly indicate a preference for mites to attach to different body parts of their hosts. It is not surprising that mites attach more frequently to the ventral surface of the thorax than to the abdomen or wings. According to Zawal & Buczyński (2013), this preference may stem from the reduced mortality of parasites located on this body region (the legs of the odonates protect parasites from mechanical harm) or from the sequence in which parasites occupy different body areas (the thorax being the primary tagma of the body that is more conducive to inhabiting and emerges first from the exuvium). Generally, the first abdominal segments are inhabited when no more space is available on the thorax. In accordance with the present results, Zawal (2004, 2006) reported that the thorax of *Enallagma cyathigerum*, *Pyrrhosoma nymphula, Coenagrion puella* and *Coenagrion pulchellum* serves as a nearly exclusive host for *Arrenurus* larvae. This finding was also supported by Baker, Mill, & Zawal (2007) for *Coenagrion puella*, with an attachment rate of 82.3%. On the other hand, abdominal attachment sites have been documented for *Lestes sponsa*, *Platycnemis pennipes* and *Ischnura elegans*. However, in *Erythromma najas*, both the thorax and abdomen were equally affected (Zawal, 2004, 2006). Previous data on wing attachment have also been noted by Cassagne-Mejean (1966), Åbro (1982), Pavlyuk (1981, 1989), Davids (1997), and Zawal & Jaskula (2008) for two Anisoptera species: *Sympetrum fonscolombii* and *Sympetrum meridionale*.

In conclusion, this study provides new insights into the infestation of water mite (*Arrenurus* sp.) in Odonata species in Souk Ahras. The highest prevalence was observed in *P. subdilatata*. The thorax was parasitized more frequently than the abdomen and wings, and no significant differences were found between male and female hosts. These findings enhance our understanding of parasitism in freshwater ecosystems. Further research is needed to investigate how host phenology, environmental factors, and life-history traits influence infestation patterns, as well as the long-term effects of parasitism on Odonata populations and ecosystem health.

CONFLICT OF INTEREST

All authors have declared that there is no conflict of interest regarding publication of this article.

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