



# Barometric pressure influences host-orientation behavior in the larva of a dipteran ectoparasitoid

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## ABSTRACT

Rain and temperature have been awarded as the most important weather factors that influence insect behavior. Barometric pressure studies have been relegated to a secondary place mainly because most studies deal with adult insects where temperature and water availability are the main environmental factors that influence behavior. We studied the influence of barometric pressure on the host orientation behavior in *Mallophora ruficauda*, an ectoparasitoid with an active host-seeking larval stage. Our results show that a steeper decrease in barometric pressure than expected by regular variation reduced orientation to host chemical cues. This study is the first to show a correlation between changes in the barometric pressure and the seeking behavior of parasitoid soil-dwelling larvae. Our results show that in this kind of insects, ambient factors other than temperature, water availability and light, can influence and have a profound impact on the process of parasitism. We discuss the influence of this behavior on a task so important for parasitoids as host location, and highlight the importance of including such information in parasitoid foraging ecology and climatic change studies.

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## 1. Introduction

It is well known that the environment influences and shapes the functioning of living organisms. This is so because biotic (plants and animals) and abiotic factors (temperature, relative humidity, pH, salinity and barometric pressure) determine the availability and accessibility of resources (Begon et al., 2006). Particularly, abiotic factors exert a huge influence on animal behavior through the mean and extreme values these variables take. In a given area, all of these variables make up what is commonly known as the weather. Variations in weather conditions can have great influence on animals changing their ecology as their distribution or feeding patterns (Begon et al., 2006).

Insects are particularly vulnerable to changes in temperature and water availability since they have a rather large ratio of surface area to volume. Temperature has direct effects on development rate and is a key factor in insect population dynamics. On the other hand, if the rate of water evaporation from the body surface is altered, wind may be important in the water balance of the insect (Gillot, 2005). However, many insects can live in suitable

microsites of the habitat that buffer exposure to environmental changes (Schowalter, 2006). The effect of these two factors on insect development and survival has been the center of intense research (Anderwartha and Birch, 1954; Messenger, 1959; Frazier et al., 2001; Chown and Nicholson, 2004). Besides these two factors, there are other environmental factors, such as the barometric pressure or time of day that might influence different behaviors in insects (Jervis, 2005; Schowalter, 2006).

Barometric pressure is the force exerted by the air at any point of the atmosphere (Villodas, 2008; Barry and Chorley, 2010). Standard barometric pressure is equal to 1013.3 hPa but there are variations in pressure levels due to the warming and cooling of the atmosphere. Also, there are regular and irregular superimposed pressure variations along time (Villodas, 2008; Barry and Chorley, 2010). The regular variations are annual and daily oscillations of the barometric pressure and are characterized by a change of a few hPa of pressure (Villodas, 2008; Barry and Chorley, 2010). The annual variations are influenced by the latitude and the major variations are observed at high latitudes. In turn, daily variations follow a bimodal oscillation with peaks at 10 and 22 h of the local time. The lower readings are registered at 4 and 16 h. This normal daily oscillation is known as a “barometric tide” (Simidchiev, 1996).

On the other hand, irregular variations are more intense and are related to weather changes in such a way that a drop in the barometric pressure usually forecasts precipitations, and barometric pressure rises precede good weather (Villodas, 2008; Barry and

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Chorley, 2010). These movements of air masses occur due to the passage of high and low pressure centers. In general, a drop of 1 hPa within a two hour interval indicates the proximity of a storm (Villodas, 2008).

For insects, the decrease in the barometric pressure is indicative of deteriorating environmental conditions and it may indicate a decrease in future opportunities to lay eggs or an increased mortality risk when migrating between patches, as might be the case in a storm provoked by a progressing cold front (Ahrens, 1993; Amat et al., 2006). Storms are usually accompanied by temperature drop, wind increase and rain humidity, which have a negative influence on most insect activities, survival and, hence, on individual fitness (Gillot, 2005). Individuals with mechanisms that allow the detection of changes in the barometric pressure would have a higher fitness and those mechanisms might aid in the avoidance of high risk mortality factors. In some insects, it has been shown that a decrease in barometric pressure can change or even interrupt behaviors such as mating activity, host-finding, mate-finding, flight initiation or patch residence time (Ankey, 1984; Casas, 1989; Keller, 1990; Roitberg et al., 1992, 1993; Steinberg et al., 1992; Wang et al., 1997; Weisser et al., 1997; Marchand and McNeil, 2000; Leskey and Prokopy, 2003). Most work has been done on adult insects that live on the ground, so there is no information available on the influence of barometric pressure on insect larvae and in soil-dwelling insects.

Field studies dealing with soil insects often quantify only the consequences of behaviors while the behaviors themselves remain hidden because the mechanisms leading to the response to environmental factors are not observable so often (Villani and Wright, 1990). The processes that occur in the soil are very different from those occurring in the air. Soil temperature influences the rates and directions of soil physical processes, energy and mass exchange with the atmosphere, the types and rates of chemical reactions, and the biological processes that take place in the soil. Also, gas exchange is an important process at the soil surface. The rates of aeration may be influenced by changes in barometric pressure, temperature gradients, and wind gusts (Villani and Wright, 1990).

Parasitoids are good models to study the effect of barometric pressure on behavior, since they usually must locate food, mates or hosts in a reliable and efficient way. They are small insects but show an astonishing array of behaviors and mechanisms to maximize their fitness (Godfray, 1994). In this work, we studied the influence of barometric pressure on the orientation behavior in the larva of the dipteran ectoparasitoid *Mallophora ruficauda* Wiedemann (Diptera: Asilidae). This parasitoid has five larval instars of which the second is responsible for locating the host (Castelo and Lazzari, 2004; Crespo and Castelo, 2008, 2010). Orientation to its host, namely the third instar larva of the white grub *Cyclocephala signaticollis* Burmeister (Coleoptera: Scarabaeidae), is performed by the detection of chemicals from the posterior intestine (Castelo and Lazzari, 2004). Unlike many other parasitoids where the female is responsible for the direct contact with the host, *M. ruficauda* has a split host-location strategy. The neonate larva is dispersed by the wind and then buries itself in the soil. Then, the larva must molt to the second instar in order to be able to orient towards a host (Crespo and Castelo, 2008). Once that larvae moult to the second instar they can survive in average for 32 days without finding a host (Crespo and Castelo, 2010). Larvae of *M. ruficauda* live underground buried only up to 30 cm below surface because hosts are associated to the most densely packed roots near the stem or to the short roots of small grasses and so they are close to the surface. The fact that larvae live close to the soil surface makes the environmental conditions important factors that influencing the larvae physiology and behaviour.

Previously studies showed that *M. ruficauda* larvae are able of discriminating the parasitism status of their host and that they

can avoid orientating to sub-optimal hosts (Crespo and Castelo, 2009). In this work we intended to: (1) unravel if the larva of *M. ruficauda* can sense changes in barometric pressure, (2) study if these changes influence the orientation behavior, and (3) ask whether there exists a threshold in the barometric pressure decrease below which host-orientation is interrupted.

## 2. Materials and methods

### 2.1. Insects

We used larvae of *M. ruficauda* that were obtained from egg clutches collected on grasslands in Moreno (34°46'S, 58°93'W), a locality associated with apiaries in Buenos Aires province, Pampas region, Argentina, in the summers of 2007–2011. Immediately after hatching, neonatal larvae were separated individually in 1.5 ml Eppendorf-type tubes, containing a small moistened piece of filter paper as substrate. Drops of mineral water were added when necessary to avoid larvae dehydration. Tubes were kept in darkness under controlled temperature (25–27 °C) until they were used in experiments.

Host stimuli used in the experiments were obtained from the hindgut of third-instar larvae of *C. signaticollis* which were collected at a soil depth of 30 cm in grasslands located in the same locality in Buenos Aires province. Once in the laboratory, hosts were identified using the taxonomic key of Alvarado (1980) and maintained individually at room temperature in black tubes filled with potting soil, and fed weekly with fresh carrot pieces. To obtain the attracting stimulus from the host's hindgut, we did an homogenate using hexane (Merck, purity  $\geq 98\%$ ) as the extraction solvent following the procedure outlined in Castelo and Lazzari (2004). Succinctly, stimulus solution was made using 15 host larvae and then stored in a freezer at  $-18$  °C during 6–9 months until experimentation in summer. This procedure had to be made as described because although third instar host and parasitoid larvae coexist in the field, stimulus solution must be prepared with hosts that are well fed and are not suffering processes as moult from second to third instar that might interfere in the experiments. Experiments, in turn, were made from December to April because it is the time when larvae of *M. ruficauda* usually appear in the field. An equivalent to 2.5 white grubs/ml was used throughout (Crespo and Castelo, 2008, 2009).

### 2.2. Experimental design

#### 2.2.1. Barometric pressure and host orientation

In order to determine the influence of a drop in the barometric pressure during host-orientation, we registered the barometric pressure with a weather station at the beginning and the end of the experiments and calculated the linear difference between them (model WH1150, Fine Offset Electronics Co., Ltd., China). The experiments were done in a dual election air-stationary olfactometer, which consists in an experimental arena that was divided into three equal size zones (one central and two lateral) along the long axis (see Castelo and Lazzari, 2004; Crespo and Castelo, 2008, 2009). Briefly it is an acrylic box of  $9 \times 6 \times 1$  cm without any air current to prevent the dehydration of the larvae. We placed a piece of filter paper impregnated with 10  $\mu$ l of either the host extract or hexane as control. In each trial, an individual larva was released at the center of the arena, and its position recorded after 90 min. In this way, three possible responses could be obtained according to the position of the larva in one of the three zones of the arena: choice for the stimulus (S), for the control (C), or no decision (ND) if the larva remained in the middle zone. Larvae that did not make a choice after the trial (ND) were not included in the

analysis of results. After every trial, each individual was discarded and the arena was cleaned up with soap and water, and then dried with an air current in order to eliminate any possible remaining cue. Each experiment consisted on a group of 20–50 individual trials ( $N = 33$ , 1387 trials). In this way, the response variable was the proportion of larvae that orientated to the zone where the stimulus was placed (S). All experiments were conducted between 10:00 and 17:00 h. under laboratory conditions ( $25.65 \pm 3.15$  °C) and in darkness. A piece of humid filter paper at the top of the arena kept the relative humidity high inside the experimental device.

### 2.2.2. Barometric pressure threshold

With the same set of experiments we performed a statistical analysis (see Section 2.3) to determine if there exists a threshold during barometric pressure decrease where larvae failed to orientate to the host stimuli. We constructed the variable “barometric pressure difference” as the subtraction of the final to the initial pressure.

### 2.3. Statistical analysis

The influence of changes in barometric pressure was analyzed by generalized additive models (GAM) with a Gaussian distribution and identity link function (Wood, 2003). The use of GAM allows fitting data when there is no *a priori* reason for choosing one parametric form over another for describing the shape of the relationship between the response and the explanatory variables. The smooth function was represented using thin plates regression splines with the best  $k$  for each variable (Wood, 2003). Barometric pressure difference between the beginning and the end of the experiment, initial pressure, temperature and larval age were included as explanatory variables in the models. Criterion as to if an explanatory variable was statistically significant, was evaluated comparing the general cross validation (GCV) score which is lower for better models (Crawley, 2007). Also, the Akaike information criterion (AIC) was used to further support the decision as to which model was better in terms of the parsimony principle (Crawley, 2007). Lower AIC values indicate that a model is better than another.

The barometric pressure threshold was analyzed by a tree model. The selected model is fitted using binary recursive partitioning, whereby the data are successively split along coordinate axes of the explanatory variables so that, at any node, the split which maximally distinguishes the response variable in the left and the right

branches is selected (Crawley, 2007). Each explanatory variable is assessed in turn, and the variable explaining the greatest amount of the deviance in  $y$  is selected. Deviance is calculated on the basis of a threshold in the explanatory variable; this threshold produces two mean values for the response (one mean above the threshold, the other below it). Statistical analyses were conducted with the program R 2.11.1 using the packages “mgcv” and “tree” (Wood, 2003,2011; Crawley, 2007).

## 3. Results

### 3.1. Barometric pressure and host orientation

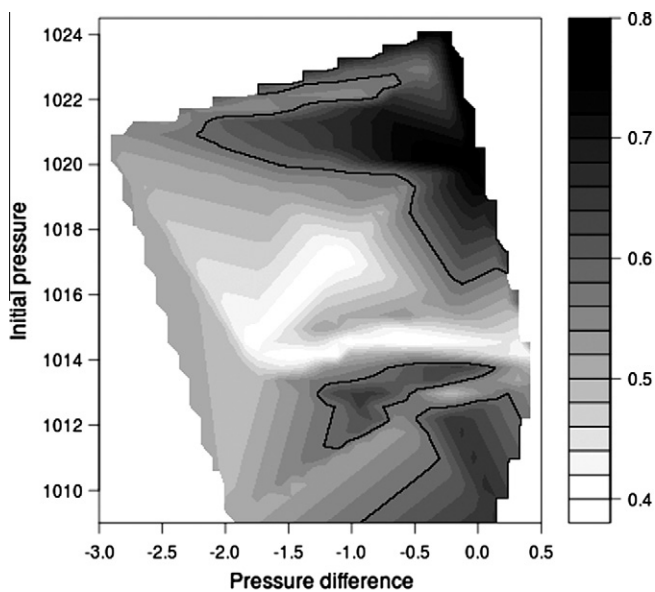
To assess the importance of the difference in the barometric pressure during the activity, the initial pressure and larval age, we constructed six models. In the full model, we included all the variables as explanatory variables (barometric pressure change during the experiment, initial pressure, temperature, larval age and year) in the model (model 1). Then, we deleted year (model 2), temperature (model 3), larval age (model 4), and temperature and larval age (model 5). Next, from model 5 we deleted initial pressure (model 6) and barometric pressure change during the experiment (model 7) alternatively. Finally, we made another model which included the interaction between barometric pressure change and initial pressure (model 8). The results for every model performance are shown in Table 1. We found no initial support to keep larval age, temperature or year in the final model ( $p = 0.539$ ,  $0.987$  and  $0.082$ , Table 1). When analyzing the performance of model 3, we found that the deletion of the variable temperature did not changed the results and so it was dropped from the model ( $p = 0.492$ ). Moreover, the GCV score and AIC showed that model 3 did better than model 2 (Table 1). Then, we analyzed model 4 where only larval age was deleted and again found that this variable should be dropped from the model ( $p = 0.804$ , Table 1). For this model, GCV score was a bit higher than for model 3 and the AIC was better for model 3. Next, model 5 was the best model of all because both its variables (barometric pressure change and initial pressure) were statistically significant and should remain in the model (Table 1). Also, GCV score was lower than for the other models and AIC was higher (Table 1). Model 6 showed that the variable initial pressure should remain in the model, since deletion of that variable caused a very low deviance explained (13%, Table 1). GCV score and AIC showed that a better performance of model 5 over model 6 (Table 1). For model 7, we found higher levels of deviance

**Table 1**  
Effect of the different environmental variables on host orientation strategy of *Mallophora ruficauda* larvae.

	s (pres.dif)			s (init.pres)			s (age)			s (temp)			s (year)			(pres.dif x init.pres)			Dev. explained	R <sup>2</sup> adj	GCV score	AIC
	EDF	F	p	EDF	F	p	EDF	F	p	EDF	F	p	EDF	F	p	EDF	F	p				
Model 1	1.955	6.040	0.009	8.081	4.316	0.003	1.000	1.173	0.292	1.000	0.027	0.871	1.000	3.375	0.082	–	–	–	66.8%	0.509	0.0075	–60.204
Model 2	1.000	6.087	0.022	6.589	3.287	0.013	1.104	1.183	0.539	1.000	0.000	0.987	–	–	–	–	–	–	65.9%	0.510	0.0090	–64.095
Model 3	1.000	6.337	0.019	6.761	3.521	0.008	1.054	0.525	0.492	–	–	–	–	–	–	–	–	–	66.0%	0.531	0.0083	–66.016
Model 4	1.000	6.714	0.016	6.942	3.450	0.009	–	–	–	1.000	0.063	0.804	–	–	–	–	–	–	65.9%	0.526	0.0085	–65.614
Model 5	1.000	7.246	0.013	7.243	3.889	0.004	–	–	–	–	–	–	–	–	–	–	–	–	66.5%	0.549	0.0078	–67.640
Model 6	1.000	4.647	0.039	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13.0%	0.102	0.0119	–50.632
Model 7	–	–	–	7.734	3.257	0.009	–	–	–	–	–	–	–	–	–	–	–	–	58.6%	0.454	0.0093	–61.662
Model 8	1.000	5.977	0.022	6.055	2.103	0.079	–	–	–	–	–	–	–	–	–	1.564	0.199	0.774	67.7%	0.558	0.0078	–68.107

**Table 2**Threshold for changes in the orientation behavior in *Mallophora ruficauda* larvae resulting from the tree model.

Barometric pressure decrease (hPa)	Initial pressure (hPa)	Average proportion of larvae found on the S zone
>0.85	<1014.80	0.484
<0.85	<1012.75	0.615*



**Fig. 1.** Orientation of *M. ruficauda* larva to *C. signaticollis* odours, and the influence of barometric pressure difference between the end and the beginning of the behavioural experiment and the initial barometric pressure. The grey color key shows the proportion of larvae found on the S (stimulus) zone in each experiment. Dark zones circled by the black lines show areas where the larvae significantly orientated to the host (at least 60%).

explained, thus showing that barometric pressure change is an important variable in the final model. In this case, GCV score and AIC again showed a better performance of model 5 (Table 1).

Up to this point, the best model included barometric pressure change and initial pressure (model 5) as the variables that explained most of the variance in the model. Finally, we added to model 5, the interaction between these two variables (model 8). When we analyzed the results, we found that there was no significant improvement by including the interaction ( $p = 0.774$ , Table 1). The GCV score was equal between both models and the AIC between models 8 and 5, showed a slightly better performance by model 8, but the overall results show that the minimal model that better explains the differences in the orientation behavior is the difference in pressure between the beginning and the end of the experiment and the initial pressure (model 5, 66.5% of the deviance).

### 3.2. Barometric pressure threshold

The tree analysis threw a threshold value for the first split of  $-0.85$  hPa (Table 2, Fig. 1). This result shows that when whenever barometric pressure decreases less than 0.85 hPa or even increases during the experiment, orientation to the host occurs. Then on a second level, the analysis showed that, when the barometric pressure decrease was higher than 0.85 hPa and the initial pressure was less than 1014.8 hPa, larvae orientated at random in the experimental arena (Table 2). However, if the decrease of the barometric pressure was smaller than 0.85 hPa and the initial pressure was less than 1012.75 hPa, a high proportion of larvae was found on

the S zone of the experimental arena (Table 2). The tree model gives place to Table 2 that shows the influence that barometric pressure decrease and initial pressure have on host orientation. It is evident that when pressure difference was lower than the threshold, host orientation is elicited more frequently regardless of initial pressure (Fig. 1, black circled areas). On the other hand, when pressure difference was higher than threshold, host orientation was interrupted (Fig. 1).

## 4. Discussion

In this work we tried to establish the relationship between barometric pressure and host location in an ectoparasitoid larva. We found that, indeed, changes in barometric pressure influence the orientation behavior and can diminish the foraging activity. Our model suggests that whenever there is a drop of 0.85 hPa or more in a 90 min period during host orientation, larvae of *M. ruficauda* do not engage in host searching. Particularly, this behavior was stronger when initial pressure was lower than  $\sim 1013$  hPa. However, initial pressure was not a determining factor when the pressure drop was small, that is, less than 0.85 hPa, or even when barometric pressure increased. These results indicate that both the magnitude of the change in the barometric pressure and its absolute value are very important factors that influences the orientation behavior and, on a second level, initial pressure also plays a role.

The influence of barometric pressure on insect behavior has been intensely studied but almost all studies were performed with adults. For the adult stage, factors that might forecast weather condition impoverishment can help the individuals to sort mortality risks by avoiding the exposure to potentially lethal storms. These weather phenomena pose severe mortality risks to adults because flying under windy and rainy conditions might kill the insect. It was observed that rapid barometric changes result in reduced flight initiation activity in *Trichogramma pretiosum* Westwood and *Trichogramma evanescens* Westwood (Fournier et al., 2005). In the aphid parasitoid *Aphidius nigripes* Ashmead, mating activity is reduced with changing barometric pressures (Marchand and McNeil, 2000). Also, decreases in the barometric pressure affect the patch residence time on leaves during host searching in the parasitoid *Encarsia formosa* Gahan (van Roermund and van Lenteren, 1995). Regarding odor discrimination, it has been shown that low barometric pressures influence the searching behavior of adult *Conotrachelus nenuphar* Herbst, resulting in a lower responsiveness to different fruit extracts (Leskey and Prokopy, 2003).

Although barometric pressure is an important factor influencing different behaviors, flying insects might also use some other environmental cues such as decreasing temperature or day length to diminish these risks. On the other side, soil-dwelling insects cannot rely on these cues to effectively avoid the consequences of a storm. A copious rain might provoke flooding and increasing levels of  $\text{CO}_2$  in the soil, which could kill the underground insects (Wu and Lee, 2011). Also, storms can modify the insect behavior impairing larval movement as seen in *Diabrotica virgifera virgifera* Le Conte (Macdonald and Ellis, 1990). However, as it is the case for *M. ruficauda*, larvae show a finely tuned system where slightly higher decreases in barometric pressure than expected from intrinsic variations, are interpreted as an advent of a storm so they do

not engage in the location of hosts. According to Alcock (1998), stimuli that trigger some kind of response deal with the proximate causes of animal behavior. In turn, the evolution of the proximate mechanisms that cause the animal to perform an activity refer to the ultimate causes. In this context, barometric pressure could serve as a stimulus that influences the larval physiology, triggering a behavioral response that increases fitness when detrimental weather conditions arise. Engaging in a task such as displacing a host, might lead to a reduction in fitness since detrimental weather conditions are usually accompanied by low temperatures and high levels of humidity. In this context, the chemical cue diffusion in the soil and liberation by the host could be reduced. This, in consequence, might provoke higher energy expenditure for larvae engaged in locating a host because of a reduced perception of the cue and an increase in the searching time. The fact that larvae respond to differences as small as 0.85 hPa could indicate an adaptive value of this behavior and show the importance of this environmental factor for avoiding the individual fitness reduction and the persistence of *M. ruficauda*. Also, it could be an expression in the larva of a behaviour that becomes useful only in the adult, or, it could indicate phylogenetic inertia, i.e. that this behaviour was useful in an ancestor species which larvae fed above ground.

The experiments undertaken in this paper, although correlational, show that at an individual level, second instar larvae of *M. ruficauda* are capable of integrating external cues and change its behavior accordingly. There are other works where we show that second instar larvae can detect the parasitism status of hosts and choose not to orientate to them (Crespo and Castelo, 2009). All the information available so far indicates that larvae of *M. ruficauda* can, as many female parasitoids, use a variety of chemical and environmental cues that help them in the host searching step. Moreover, although there exist few studies showing a combined effect of artificial barometric pressure and humidity variation on larva development duration, survival and tolerance during diapause process, under a pest population control context (Davenport et al., 2006; Johnson, 2010; Mbata et al., 2012), this is the first work showing modulation exerted by natural environmental barometric pressure in the foraging behaviour of insect larvae.

At a population level, weather influence (rain and temperature) on insects has been studied mainly as a key factor on population dynamics determining abundance (Gillot, 2005). Some studies show that rain can provide oviposition sites for some mosquitoes, or might serve as a cue in the termination of diapause (Gillot, 2005). In *Schistocerca gregaria* Forskål, the arrival of rain is used as a cue for copulation, dispersal and oviposition (Denlinger, 1986; Gillot, 2005). On the other hand, temperature might impose limits to insect populations. In the fall webworm *Hyphantria cunea* Drury and the spruce budworm *Choristoneura fumiferana* Clemens, temperature changes can influence on the developmental time of these two forest pests larvae or can give rise to outstanding population outbreaks (Gillot, 2005). The influence of rain and temperature has been shown to be of great importance in population dynamics of many species and it is why influence of barometric pressure has been much less investigated but, as shown in this work, it can have important consequences on behaviours directly linked to individual fitness.

Theory regarding fitness related behaviors states that underlying mechanisms leading to a given individual behavior should be subject to strong selective pressures given its influence on the animal biology, and consequently on individual fitness (Alcock, 1998; van Alphen et al., 2003). In this sense, some of the most studied and better understood behaviors, where barometric pressure exerts a strong influence, are food foraging, defensive responses and mating in flying insects because of either its economic or biological relevance (Edwards, 1961; Southwick and Moritz, 1987;

Riessberger and Crailsheim, 1997; Marchand and McNeil, 2000). Particularly, oviposition is one of the best studied behaviors because of its direct link with fitness (Rousse et al., 2009). However, in parasitoids with host seeking larvae, a successful location of the host is equivalent and as important to their fitness as it is oviposition for parasitoids where the female place the egg directly onto the hosts. From a wider picture, the results presented here show for the first time how changes in the environment can impact profoundly on the parasitism dynamics of parasitoids with host-seeking larvae. In this sense, factors that modify local environmental scenarios can influence the parasitism success not only in parasitoid species where females locate hosts, but on a whole understudied fauna living underground. This fact is reflected in studies showing that differences in thermal performance curves promoted by climate change can influence the development of both parasitoid and host and the results of population interactions (Hance et al., 2007). For instance, in the braconid *Microplitis rufiventris* Kokujev parasitism is less effective at higher than at low temperatures (Blumberg, 1991). In this sense, a general increase in the average temperature increases the capacity of hosts to defend themselves against immature parasitoids, resulting in a decrease in parasitism success (Hance et al., 2007). At a big scale scenario, the capacity of parasitoids to increase the geographical distribution following a climate change is limited by their hosts react to these changes (Hance et al., 2007).

At a population level, environmental factors at habitat scale can alter the temporal synchronization between host and parasitoid cycles, promoting the lack of encounter and disrupting the equilibrium (Hance et al., 2007). This effect is more pronounced in selective parasitoid species, which rely in a precise synchrony with the development of their unique host. Temperature is one of the major factors that can alter this scenario because it may uncouple the phenological synchrony between parasitoids and hosts, because insects are highly susceptible to temperature and humidity changes. At a large temporal ecological scale, climate change can drive to this kind of situation if the species of a given system is susceptible to perdurable changes in temperature or rainfall regimes (Hance et al., 2007). In this scenario, barometric pressure might be another factor modified by climate change that might uncouple the physiological or behavioral responses of insects that are intimately fitness related. An analysis on how parasitoids react to changes in barometric pressure is needed to estimate, together with temperature, the consequences of global change at the individual level that rely on the ultimate causes of behaviour.

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