The effect of environment on development and survival of pupae of the necrophagous fly *Ophyra albuquerquei* Lopes (Diptera, Muscidae)

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ABSTRACT. The effect of environment on development and survival of pupae of the necrophagous fly *Ophyra albuquerquei* Lopes (Diptera, Muscidae). Species of *Ophyra* Robineau-Desvoidy, 1830 are found in decomposing bodies, usually in fresh, bloated and decay stages. *Ophyra albuquerquei* Lopes, for example, can be found in animal carcasses. The influence of environmental factors has not been evaluated in puparia of *O. albuquerquei*. Thus, the focus of this work was motivated by the need for models to predict the development of a necrophagous insect as a function of abiotic factors. Colonies of *O. albuquerquei* were maintained in the laboratory to obtain pupae. On the tenth day of each month 200 pupae, divided equally into 10 glass jars, were exposed to the environment and checked daily for adult emergence of each sample. We concluded that the high survival rate observed suggested that the diets used for rearing the larvae and maintaining the adults were appropriate. Also, the data adjusted to robust generalized linear models and there were no interruptions of *O. albuquerquei* pupae development within the limits of temperatures studied in southern Rio Grande do Sul, given the high survival presented.

KEYWORDS. Azelinae; facultative predator; forensic entomology; garbage flies; Neotropical.

The interval of time between the death and the discovery of a corpse is considered the postmortem interval (PMI) and has fundamental importance in investigations of murders and other crimes. This information can help to identify both the criminal and the victim, eliminating suspects and linking the corpse discovered to the missing persons to the PMI estimation.

PMI depends on many factors (Micozzi 1991; Campobasso et al. 2001) and therefore can be extremely difficult to determine (Bass 1984), mainly because of the time-dependence of chemical and physical changes. In PMI longer than three days, the ecological data (Wells & LaMotte 2010) of necrophagous insect species, mainly flies of the families Calliphoridae, Sarcophagidae and Muscidae, are more robust than traditional methods for determining PMI (Smith 1986).

Temperature is the most important source of variation in the rate of development of immature stages of these flies, and secondarily, humidity and rainfall (Higley & Haskell 2010).

Temperature changes throughout the day can influence the estimates of PMI, especially when the expert uses models built from constant temperatures (Higley & Haskell 2010; Krüger et al. 2010). Many studies of fly developmental rates occur at controlled temperatures (Greenberg 1991; Byrd & Butler 1998; Marchenko 2001; Grassberger & Reiter 2001), without consideration of variation of temperature and its interaction with other abiotic factors (Tachibana & Numata 2004; Naby et al. 2007; Higley & Haskell 2010). It becomes necessary to consider the influence of factors other than temperature on the development of immature stages of carrion flies in order to generate robust models applied to forensic entomology (Campobasso et al. 2001; Krüger et al. 2010). One of the stages most susceptible to temperature is the pupa, which in most cases occurs in the soil near the corpse (Gomes et al. 2006; Zimmer et al. 2010).

Species of *Ophyra* Robineau-Desvoidy, 1830 occur in carrion bodies in decomposition (Couri et al. 2008; Segura et al. 2009; Rosa et al. 2009; Horenstein et al. 2010;
The development time (D) of species, measured in days, was transformed to development rate (1/D). The influence of \( mt \) (mean daily temperature), \( rh \) (relative air humidity) and \( vp \) (rainfall) on pupal development rate (explanatory variable) was assessed according to linear model (LM) with \( F \) distribution and between the months by ANOVA with distribution \( F \).

The influence of \( mt \) (mean daily temperature), \( rh \) (relative air humidity) and \( vp \) (rainfall) on pupal survival (explanatory variable) was assessed according to generalized linear models (GLM) with quasibinomial proportional distribution of errors to correct over dispersed data (Crawley 2007).

All tests were performed in R statistical software (R Development Core Team 2009), and the level of significance used was \( p < 0.05 \).

**RESULTS**

The temperature (\( mt \), Fig. 1A), relative air humidity (\( rh \), Fig. 1B) and rainfall (\( vp \), Fig. 1C) varied over the months of the trial and influenced the development rate (rate) of pupae of \( O. \) albuquerquei (\( F_{3, 107} = 328.32, p < 0.001, r^2 = 0.899, \text{Fig} \ 2) \). The influence of these factors determined the model: rate = \(-0.202 + (0.005326 \times mt) + (0.002196 \times rh) − (0.000209 \times vp)\).

![Graphs](image-url)

**Fig. 1.** Average daily temperature (A), average relative air humidity (B) and average daily rainfall (C) between June 2002 (a) and May 2003 (l) in the environment.

In this model, considering the adjusted regression coefficient (\( r^2_{adj} \), the temperature explains 56.61% of the variation of the data related to development rate (rate); 22.69% rainfall and relative humidity less than 10%. By adding the rainfall, the model increases the adjusted \( r^2 \) from 56 to 79. Including further a variable \( rh \), the model explains over 10%.
The rate of development varied between months ($F_{11,99} = 596.47, p < 0.001$) (Fig. 2) and survival was not influenced by the average daily temperature, daily mean relative air humidity and mean daily rainfall ($\chi^2 = 193.78, p = 0.069$) and ranged from 85% to 99% between the months (Fig. 3).

A combination of high temperature and relative humidity with low rainfall (Fig. 1) increased the rate of development (Fig. 2) and did not affect the survival of pupae (Fig. 3). In contrast, when the relative humidity decreases and the temperature is high as in January (Fig. 1), the rate of development of pupae decreased (Fig. 2), with the lowest survival rates (Fig. 3).

The range of factors throughout the year and subsequent interaction of these variables (Fig. 1) increased the variability of the rate of development (Fig. 2). This has direct implications in the analysis of development data as observed by Ikemoto & Takai (2000) and Richards & Villet (2008). Richards & Villet (2008) call attention to the variation of the thermal constant, necessary to estimate the ADD. This estimate may vary depending on the development measures minimum and maximum. This study considered the means of development of pupae per vial, and the variation was not significant between the vials exposed to the same month, but between the months. Therefore, it is more likely that the variation has been caused by the interaction of factors or by the physiology of individuals at minimum and maximum temperatures.

The data imply that temperatures below 15°C are not limiting to the development and survival of pupae of Ophyra, and that perhaps the populations of these species are able to resist environmental adversity at this stage. According to Costa et al. (2000) and Ribeiro et al. (2001; Lefebvre & Pasquerault 2004). The main difference in respect to other studies is the importance of relative humidity and rainfall for the development of pupae of O. albuquerquei. The influence of rainfall was 23% in explaining the model, which maximizes the rate of development, while relative humidity explains only about 10% of the variation found.

The relative humidity will interact with temperature to control the evaporation rate of the insect body. In March occurred a combination of high temperature and relative humidity with low rainfall (Fig. 1), which increased the rate of development (Fig. 2) and did not affect the survival of pupae (Fig. 3). In contrast, when the relative humidity decreased and the temperature is high as in January (Fig. 1), the rate of development of pupae decreased (Fig. 2), with the lowest survival rates (Fig. 3).

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The data imply that temperatures below 15°C are not limiting to the development and survival of pupae of Ophyra, and that perhaps the populations of these species are able to resist environmental adversity at this stage. According to Costa et al. (2000) and Ribeiro et al. (2000c), this temperature would be limiting for the maintenance of populations of O. aenescens because of the low probability of capture of adults in the environment. This finding cannot be taken as evidence of the absence of populations of these species, since the pupae can survive and develop in winter temperatures, including laboratory data that confirm this for O. aenescens (Ribeiro et al. 2000a, 2000b, 2001; Lefebvre & Pasquerault 2004).

Another point is that the O. albuquerquei is greater than O. aenescens (RF Krüger data not published) and because it has higher rate of development (Krüger et al. 2003). In consequence, the accumulation of fat is greater in the puparia of...
O. albuquerquei than O. aenescens, providing more thermal insulation. Moreover, the period of greatest development is influenced by more ranges of temperature favoring development at low temperatures.

Interestingly, the temperature variation over the year did not influence the survival of pupae of O. albuquerquei, as expected. The variation of this factor in the laboratory alters the survival of specimens of other necrophagous flies such as O. aenescens (Ribeiro et al. 2000a, 2000b). The results demonstrated the adaptive capacity of O. albuquerquei to this region, thus reiterating its forensic importance to southern South America (Moura et al. 1997; Souza et al. 2008; Patitucci et al. 2010).

We concluded that the high survival rate observed suggested that the diets used for rearing the O. albuquerquei were appropriate. Another conclusion is that it was possible to adjust the data to robust generalized linear models because the temperature limits in southern Rio Grande do Sul did not disrupt the development of this species.

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REFERENCES


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