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SHORT COMMUNICATIONS

POPULATION DYNAMICS OF *HETAERINA ROSEA* SELYS AND ITS RELATIONSHIP TO ABIOTIC CONDITIONS (ZYGOPTERA: CALOPTERYGIDAE)

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Aspects of population dynamics were tested against temperature, insolation and moisture. The monthly abundance of *H. rosea* was estimated utilizing a scan method based on 49 fixed areas in 30-min intervals from 0800 to 1700 h during the day. The daily ♂ activity pattern is characterized by a sharp increase at 0900 h with continuous density until 1430 h, followed by a sharp decrease after 1600 h. A correlation between peak densities was observed during the year and high period of photoperiod and low evapotranspiration suggesting possible ways ♂♂ can adjust their emergence periods to optimize water loss with longer reproduction periods of activities.

INTRODUCTION

In many odonate species, males defend territories near streams and females spend most of their time at other places foraging (CORBET, 1962, 1980; MOORE, 1987; DE MARCO, 1998). Sometimes numerous species occur at streams, including some large Calopterygidae that are dominant in these communities in neotropical areas (PERUQUETTI & DE MARCO, 2002).

The activity pattern of species of medium to small size, like those in the Calopterygidae, is expected to be more affected by temperature and moisture due to the heat surface/volume ratios (MAY, 1979, 1991; HEINRICH, 1993; TAUBER et al., 1998). Besides well-known ecophysiological effects on developmental rate (PRITCHARD & LEGGOTT, 1987; PRITCHARD, 1989; PICKUP & THOMPSON, 1990; KRISHNARAJ & PRITCHARD, 1995), temperature could also affect prey aquisition rates in odonate

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larvae and probably the food availability in the ecosystem (CROWLEY & JOHNSON, 1982; NEIFF & POI DE NEIFF, 1984). Insolation (amount of time with direct exposition to sun) is another important component affecting a species' reproductive behaviour thus limiting time for territorial defense during the day. This factor may have a great influence in habitats where the amount of insolation is variable and mainly for species that have a short life span.

As in temperate regions, many climatic factors in neotropical regions can be variable. This was shown by Wolda (WOLDA, 1978, 1987; WOLDA et al., 1992) who demonstrated that tropical ecosystems could show considerable fluctuation in insect populations due to local climatic variations. Nevertheless, tropical insects also must deal with diel variations which have shaped many of their thermoregulatory and ecophysiological adaptations. Can those adaptations to diel rhythm affect adaptations to seasonal variation of the same environmental factor?

Hetaerina is a large calopterygid genus, occurring in the neotropical and neartic regions with 37 species (GARRISON, 1990), but only five of these (from USA and Mexico) have been the subject of behavioral studies (*H. americana* JOHNSON, 1961; GRETHER, 1996; *H. titia* JOHNSON, 1961; *H. vulnerata* ALCOCK, 1982; *H. cruentata* CÓRDOBA-AGUILAR, 1994, 1995 and *H. macropus* EBERHARD, 1986). More detailed studies on evolutionary aspects of reproductive behavior are essential for a proper comparative analysis (HARVEY & PAGEL, 1991).

In this study we examine the relationship of daily environmental factors to yearly environmental fluctuations for a common, locally abundant lotic damselfly in southeastern Brazil.

METHODOLOGY

STUDY AREA. – Studies were carried out at the São Bartolomeu stream near an urban area (Romão dos Reis) in Viçosa, Minas Gerais, southeastern Brazil (20°46'13.0''S, 42°53'1.83''W). The main habitat was heavily disturbed by domestic animals and by a sewage station. The stream fluctuated from 0.5 to 1.0 m wide annualy, depending on precipitation. Pasture and some trees surround the study area.The region has a subtropical climate (CWb in Köppen classification) with a dry season between April and July (GOLFARI, 1975). Mean annual precipitation is 1450 mm with mean moisture around 80% and mean monthly temperature between 14,0°C and 26.1°C (VALVERDE, 1958). This area was chosen due to the high abundance of *Hetaerina* species in a previous study of the odonate fauna of the region (PERUQUETTI & DE MARCO, 2002).

DAILY ACTIVITY PATTERN. – We estimated the number of individuals near the stream by careful inspection of 49-2 m length segments at 30-min intervals from 0800 to 1700 h during peak density (April-May 2001). We recorded air temperature in sunny and shadowed areas during these observations.

CLIMATE INFLUENCE ON *H. ROSEA* POPULATION DYNAMICS. – To estimate monthly the abundance of *H. rosea*, we used a scan method (DE MARCO, 1998) based on fixed areas divided into 49 segments, each 2 m in length during a 21 month interval. We observed each segment to count all individuals that were present. This procedure took less than 30 s by segment to avoid overestimate density by recount passing individuals. Individuals were marked with non-toxic black ink in order to uniquely identify them. A total of 518 individuals were marked during this study. To determine population abundance, only the data between 1000 and 1400 h were used, because this was the period with high activity. These samplings were taken at least three times during each month. Temperature, rainfall, evapotranspiration, and insolation were recorded at the meteorological station of the Federal University of Viçosa (online service at ftp.ufv.br/Dea/

DadosClima).

STATISTICAL ANALYSIS. — To determine months with peak abundance of males or females in the S. Bartolomeu stream, we considered the upper 25% values during the period of study, as "peak" population times and a minimun of 0.55 individuals/segment was used to determine "peak" male populations and 0,020 for peak female population. To determine the relationship of climate factors on the probability of peak densities we employed a multiple logistic regression analysis according to HOSMER & LEMESHOW (1989). To determine the effect of these same climate factors on population fluctuation we used a multiple regression approach according to standard statistical methods (ZAR, 1999).

DAILY ACTIVITY PATTERN

Odonate activity included behavioral activities (territorial defense, reproduction, foraging) of adults at the stream. Male activity patterns of *H. rosea* during the day was characterized by a sharp increase at 0900 h and continuing abundance until 1430 h (Fig. 1). Activity began to decrease after this time and usually no individuals were observed after 1600 h (resulting in a total of 8 hours of activity).

We observed a strong decrease in activity (at least 75% of total abundance) when clouds shadowed the sun (Fig. 2). Adults were most active during the hottest moments of the day. We found no relationship between mean male activity and temperature during the day (Linear regression; $R^2 = 0{,}006$; df = 17; p = 0,306). In general, activities are fairly stable between 0930 and 1430 h.

CLIMATIC INFLUENCE ON *H. ROSEA* POPULATION DYNAMICS

We observed a clear seasonal variation in the population size during the year; peak population abundance occurred at the rainy season. The probability of occurrence of a

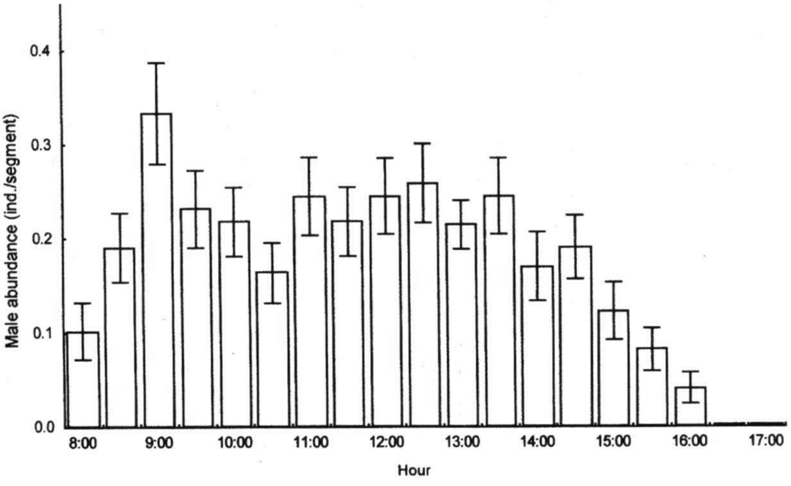

Fig. 1. Daily activity patterns of male *H. rosea* near the water body (bars represent the standard error).

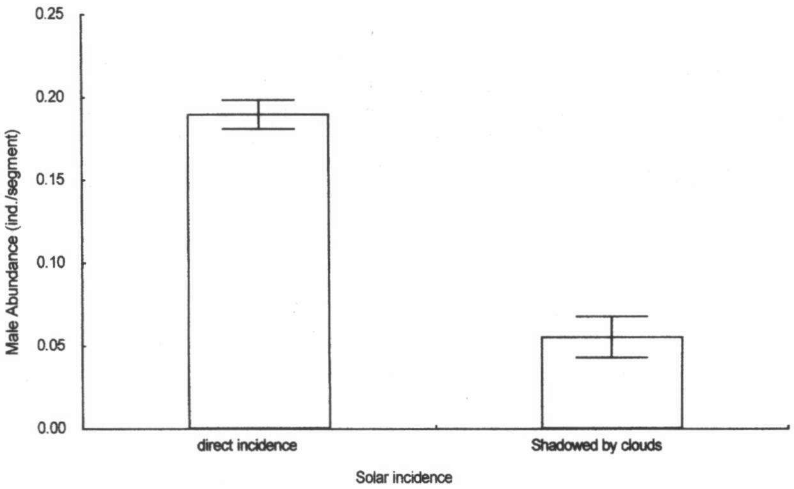

Fig. 2. Male activity of *H. rosea* near the stream as a function of solar incidence (bars represent the standard error).

population peak increases with insolation and decreases with evapotranspiration (Logistic regression; $\chi^2 = 7,837$; df = 1; p = 0,019, Tab. I). This species may have a life cycle adjusted to emerging during "fresh" climatic conditions without great loss of humidity. Increase in insolation also allows more time for reproductive activities in males. Both of these conditions occur after the onset of heavy rains (from December to March) and before the beginning of the dry season (June-July, Fig. 3).

Females showed a similar pattern but with very low abundance during all year (Fig. 5); we found no relation between female abundance and insolation and evapotranspiration (Logistic regression; $\chi^2 = 2,157$; df = 1; p = 0,340). During field observations females spent most of their time away from the water, usually perched in bushes and trees nearby. When not engaged in reproductive activities, they were frequently seen in areas shadowed by trees at the stream.

Table I
Estimated parameters to the dependence of male *H. rosea* abundance on environmental factors based on a logistic regression ($\chi^2 = 7,837$; df = 2; p = 0,019)

	Constant	Evapotranspiration	Insolation
Estimates	-0,560	-2,936	1,299
Standard error	4.556	1.886	0.684

Population dynamics of *H. rosea* males show a close relation to environmental fluctuation with an increase in abundance in when air temperatures are high and a decrease with evapotranspiration and rainfall (Tab. II).

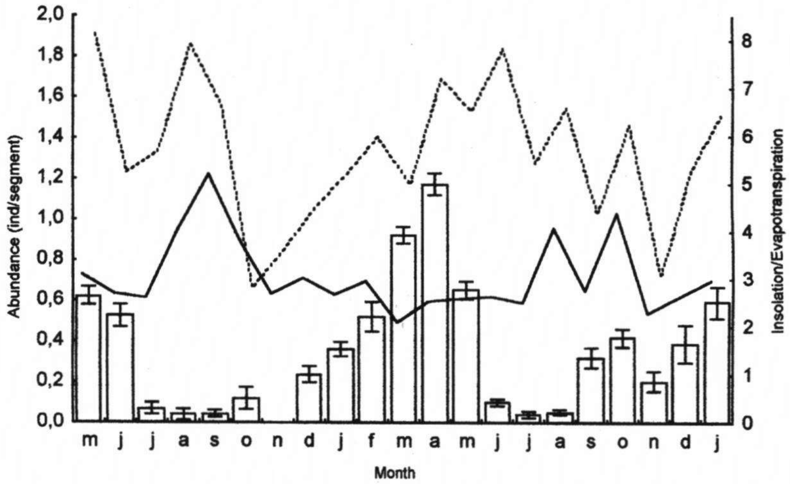

Fig. 3. Population dynamics of male *H. rosea* (columns). Bars represent standard error. The lines represent evapotranspiration (solid line) and insolation (dashed line).

DISCUSSION

DAILY ACTIVITY PATTERN. — Odonate activity in reproductive areas are controlled by many environmental conditions including luminosity (DE MARCO & RESENDE, 2002) and air temperature (MAY, 1977; HILFERT-RÜPPELL, 1998). Thermoregulatory theory predicts that both irradiated heat (related to direct exposition to sun) and convection heat (related to air temperature) may controll insect activity. Irradiated heat exchange is directly correlated to insect body surface but convection heat exchange depends on the surface/volume ratio which decreases with body size (MAY, 1976, 1991; DE MARCO & RESENDE, 2002). Thus, small insects have higher convection heat exchange and are considered thermal-conformers while larger insects have higher irradiated heat exchange and are classified as heliotherms (MAY, 1991). Is there a mini-

Table II
Multiple regression analysis for the population fluctuation of *H. rosea* males — [*t* = t-student statistic; — *p* = probability level; — all tests with 15 degrees of freedom]

	Coef.	Std error	*t*	*p*
Intercept	-1.493	0.621	-2.405	0.029
Mean air temperatures	0.127	0.035	3.636	0.002
Rain fall	-0.086	0.036	-2.384	0.031
Evapotranspiration	-0.241	0.067	-3.561	0.003
Insolation	0.063	0.042	1.506	0.153

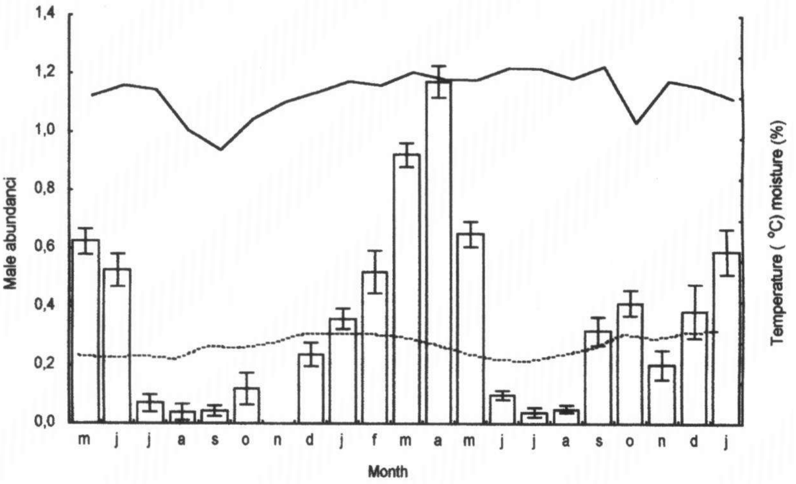

Fig. 4. Population dynamics of male *H. rosea* (columns). Bars represent standard error. The lines represent moisture (solid line) and temperature (dashed line).

mum surface/volume ratio which can predict whether an insect's daily activity can be affected by temperature or luminosity?

Many studies on Anisoptera (mostly Libellulidae) have attempted to show a gradation in the adaptive traits related to thermoregulation as body size increases (MAY, 1976; DE MARCO & RESENDE, 2002). If we compare zygopterans and anisopterans, we might expect the former group to be mainly thermal comformers (MAY, 1991) due to size differences, although, as in Libellulidae, there is a large size variation within Zygoptera. For example, it is possible that larger species like *H. rosea* compared to other, smaller Zygoptera have their activity primarily controlled by luminosity.This adaptation may allow *H. rosea* to stay active during a large part of the day while showing strong response to daily temperature variations. This may amplify mating opportunities and success in maintaining territories. If males that arrive earlier have major chances in acquiring and keeping a territory, the capacity to begin activity and to maintain it for longer periods of time may increase their probability in keeping a territory and mate.

If this hypothesis is correct, individuals that emerge during periods of longer daily photoperiod (insolation time), could have more mating opportunities. This phenomenon can be important in life history tactics within species, mainly, in regions where photoperiod varies between months. In our study area, insolation time between months varied from 6 hours (2.8 hours on October/99 to 8.1 on May/99). Species in temperate latitudes can show similar responses to cold temperatures or feezing during winter. The main adaptive responses are development delay, including diapause mechanisms (PRITCHARD, 1989), and/or increased growth rate in periods before winter (JOHANSSON & ROWE, 1999).

CLIMATIC FACTORS AFFECTING POPULATION DYNAMICS. — Male population peaks are related to months of low evapotranspiration rate and long photoperiod duration. This phenomenon may occur as a result of an adjustment in larval eclosion and could evolve in two main ways with one related to life history characteristics, and the other to behavioral changes: (1) It is possible that larvae have their development completed during a year like many odonate species (e.g. PARR, 1970; DUDGEON & WAT, 1986; DUDGEON, 1989; PRITCHARD, 1996) and individuals that oviposit in months with optimal climatic conditions may have more descendants in comparison with individuals that oviposit during other periods; — (2) Larvae can change their development rate in order to emerge when conditions of adult survivorship are better. Larvae may perceive the onset of adverse times and show specific responses to this. These responses may determine rates and increments of developmental times.

The difficulty in testing the second hypothesis, is determining a causal relation between insolation and evapotranspiration with larval development rate, that is usually associated with temperature (PRITCHARD & LEGGOTT, 1987; PRITCHARD, 1989). Incremental growth rate when an enviromental constraint is coming like that demonstrated to *Lestes congener* (JOHANSSON & ROWE, 1999) is a possibility. In this scenerio, characteristics related to perception of environmental clues may function as a physiological trigger to accelerate developmental rate and activity. The main trigger in many insect species is photoperiod which affects reproduction time (TAYLOR, 1986), diapause induction (TAYLOR & SPALDING, 1986) and changes in developmental rate (JOHANSSON & ROWE, 1999). The dependence of the *H. rosea* population dynamics to insolation can be, at least in part, a result of this phenomenon.

PRANGE (1996) claimed that water loss in relation to body surface is more pro-

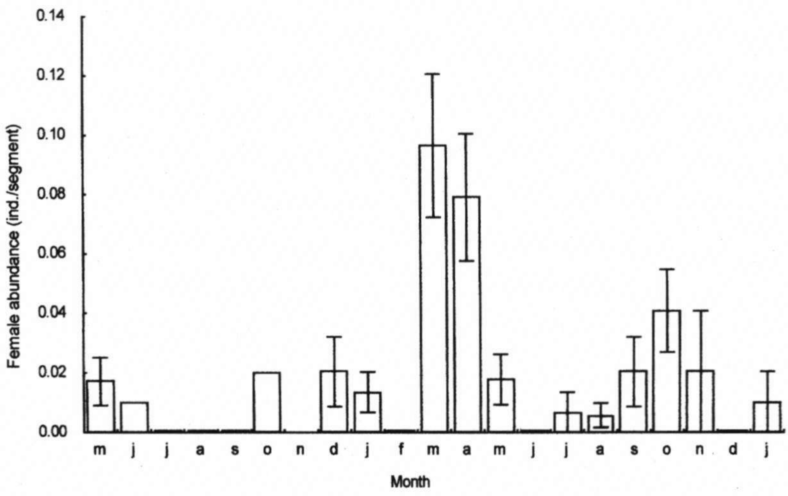

Fig. 5. Population dynamic of female *H. rosea* (columns). Bars represent the standard error.

nounced in smaller insects. Thus, climatic conditions may be more important in regulating small insect population dynamics like *H. rosea*. Population peaks of male of *H. rosea* may correlate to low probability of low water loss and long photoperiod.

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