PATTERNS OF ADULT EMERGENCE AND MATING IN *MICROMUS TASMANIAE* (WALKER) (NEUROPTERA: HEMEROBIIDAE)

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ABSTRACT

The Tasmanian lacewing, *Micromus tasmaniae* Walker, is an important predator of a number of economically important pests such as aphids. This study was to investigate the patterns of adult emergence, sexual maturation and mating of *M. tasmaniae* in the laboratory at 21±1°C, 60% RH and 16:8 h (light:dark). Results indicate that adult emergence peaked 3 h before the scotophase began. There was no significant difference in emergence patterns between males and females (P>0.05). The sexual maturation period of males and females was 47.8±2.5 h and 65.1±3.1 h after emergence, respectively, and this difference was significant (P<0.0001). Mating success significantly increased from the first to the eleventh hour after the photophase began. The importance of these results in understanding the lacewing's reproductive biology and the application of such information to improve biological control is discussed.

Keywords: *Micromus tasmaniae*, emergence, sexual maturation, mating.

INTRODUCTION

The Tasmanian lacewing, *Micromus tasmaniae* Walker (Neuroptera: Hemerobiidae), is an important aphidophage widely distributed in Australia and New Zealand (Wise 1963). In New Zealand, its biology and ecology have been studied in the field (Hilson 1964; Leathwick & Winterbourn 1984). Studies were also made on its predation and development under constant and fluctuating temperatures (Islam & Chapman 2001) and photoperiods (Yadav et al. 2008). Its ability to control *Acyrthosiphon kondoi* Shinji and *A. pisum* (Harris) on lucerne (*Medicago sativa* L.) (Cameron et al. 1983; Leathwick & Winterbourn 1984; Rohitha & Penman 1986) and greenhouse capsicum crops (Harcourt 1996) has also been evaluated. Consequently, it has been suggested that *M. tasmaniae* could be an important component of integrated pest management (Rumph et al. 1997).

Circadian clocks are endogenous timing mechanisms that control molecular, cellular, physiological and behavioural rhythms in all organisms (Giebultowicz 2000). In insects, activities such as hatching, moulting, pupation and emergence, are usually rhythmic (Saunders 1982). The study of circadian emergence rhythms elucidates the spatial and temporal distributions of abundance of individuals, which is important for interpreting adult sampling estimates (Quiring 1994). Circadian rhythms influence many aspects of insect biology, fine-tuning life functions to the temperature and light cycles associated with the solar day (Giebultowicz 2000). Furthermore, variations in circadian rhythmicity can reduce direct competition between species that share resources, and synchronise mating activities to ensure genetic isolation of sibling species (Saunders 1982).

The timing of adult emergence could play a vital role in the success of sexual activity and reproduction of a natural enemy. For example, in *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae), early emergence may enable males to mature sexually before the emergence of females and subsequently enhance their capacity to induce higher receptivity in females (Doyon & Boivin 2006).

Although most Chrysopidae lacewings are active principally in the evening or at night, sexual activity is often observed during daylight hours as well, especially in highly receptive individuals (Henry 1984). Yadav et al. (2008) reported that *M. tasmaniae* can feed on pea aphids in both photophase and scotophase, but the circadian emergence and sexual activity rhythms were still unknown prior to the present study. To provide information for the development of mass-rearing and field release techniques and to better understand the ecology of *M. tasmaniae*, the circadian patterns of adult emergence, sexual maturation and mating of *M. tasmaniae* were investigated in the present study.

MATERIALS AND METHODS

Insects

A breeding colony of *M. tasmaniae* was obtained from a commercial insectary (Zonda Resources Ltd, Pukekohe, New Zealand) during October 2007 and maintained in the Entomology and IPM Laboratory of Massey University, Palmerston North. Thirty adults were housed in plastic oviposition containers (17 cm diameter × 24 cm height), with four fine nylon mesh windows (6 cm diameter). They were fed with first to third instar pea aphids (n = 10 aphids/adult) reared on potted broad bean plants. A black cotton sheet (12 cm × 12 cm) was placed at the bottom of the plastic container for oviposition (Miller & Cave 1987). The container was examined every 24 h and eggs laid on the cotton sheet were placed in plastic boxes (17 cm length × 12 cm width × 7 cm height) for hatching. The newly hatched larvae were further reared on pea aphids in groups of 40-50 larvae, in the plastic boxes mentioned above, and emerged adults were used for further rearing. All experiments were carried out at 21±1°C, 60% RH and 16:8 h (light:dark).

Circadian emergence pattern

To observe the 24-h emergence patters of *M. tasmaniae*, two bioassay rooms were set up in which the photophase in one room was set from 0800-2400 hours (normal-light regime) and in the other room the scotophase was between 1000-1800 hours (reverse-light regime). Insects used in these experiments were mass reared for two generations in these bioassay rooms before being used for this study. The newly hatched larvae were transferred individually to a clean glass vial (2.5 cm diameter × 8.0 cm height) with a fine nylon mesh circular window (1.2 cm diameter) in the lid. Five, 10 and 20 pea aphids were provided twice a day to 1^{st}, 2^{nd} and 3^{rd} instar larvae, respectively, until they pupated. The emergence was observed from 458 pupae in photophase in the normal light regime and from 430 pupae in scotophase in the reverse-light regime. The emergence incidence was recorded hourly and emerged adults were sexed.

Sexual maturity

Because previous investigations had indicated that most matings occurred during the photophase (A. Yadav, unpubl. data), all experiments on sexual maturity were carried out during the photophase. The preliminary observations had shown that females became sexually mature about 3 days after emergence and males about 2 days after emergence (A. Yadav, unpubl. data). To determine the sexual maturation period of adult *M. tasmaniae* more accurately, two experiments were set up: (1) virgin males that were 0, 8, 24, 32, 48, 56, 72 and 80 h old were individually paired with 3-day-old virgin females, and (2) virgin females that were 0, 8, 24, 32, 48, 56, 72 and 80 h old were individually paired with 2-day-old virgin males. Twenty-four individuals were tested in each experiment.

In experiment (1), at the start of photophase 24 newly emerged virgin males (i.e. 0-h-old) were individually paired with a 3-day-old virgin female in a clean glass vial for 8 h. If the male remained unmated at 8 h old it was then immediately paired with another 3-day-old virgin female for another 8 h in the next mating bout. If unmated, the male was removed from the female during scotophase, and then at 24-h-old it was paired with another 3-day-old virgin female for 8 h. This process continued for 4 days until all the males had mated. The same experimental design was used in experiment (2). The pairs were observed every 15 min during each 8-h test period, and the insects were considered to have become sexually mature if mating had occurred.

Mating pattern

To determine the mating pattern of *M. tasmaniae* during the 16 h photophase, a 3-day-old virgin male and a 3-day-old virgin female were paired in a clean glass vial at the start of photophase. Sixty-four pairs were established for this study. These containers were observed every 15 min. Upon mating, the time at which copulation occurred and mating duration were recorded.

Statistical analysis

A paired t-test was used to determine the difference in emergence patterns between males and females. Data on emergence in the photophase and scotophase and sexual maturity were normally distributed and were analysed using ANOVA. The mating pattern was described using a quadratic equation: $y = a + bx + cx^2$, where y is the number of matings that occurred, x is the hours after the start of the photophase, and a, b and c are the parameters of the equation. Because no mating occurred during the last 3 h in the photophase, data collected in the first 13 h of photophase were included for analysis (Regression Procedure, SAS 9.1, SAS Institute 2006, Cary, North Carolina, USA).

RESULTS

Circadian emergence pattern

In both bioassay rooms, all adults emerged, and significantly more adults emerged in the photophase (352.5±5.5) than in the scotophase (91.5±19.5) (P<0.0001). For the bioassay room with photophase between 0800 and 2400, adult emergence peaked 3 h before the start of scotophase (Fig. 1). There was no significant difference in emergence patterns between males and females (P>0.05).

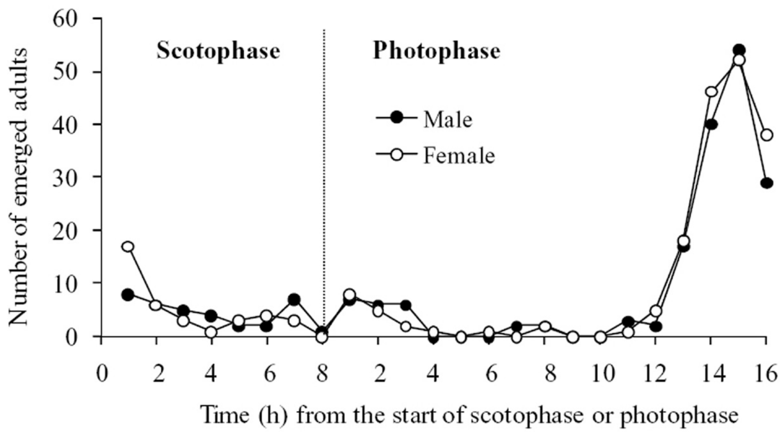

FIGURE 1: Emergence of male and female *M. tasmaniae* adults in the scotophase and photophase.

Sexual maturity

The period required by *M. tasmaniae* males to become sexually mature (46.2±1.9 h after emergence) was significantly shorter than that of females (65.1±3.1 h) (P<0.0001).

Mating pattern

The quadratic model predicted that the time at which copulation occurred significantly increased from the first to the eleventh hour after lights on, after which no further increase occurred (P<0.05) (Fig. 2). No mating was observed during the last 3 h in the photophase. The average mating duration was 181.6±3.7 min.

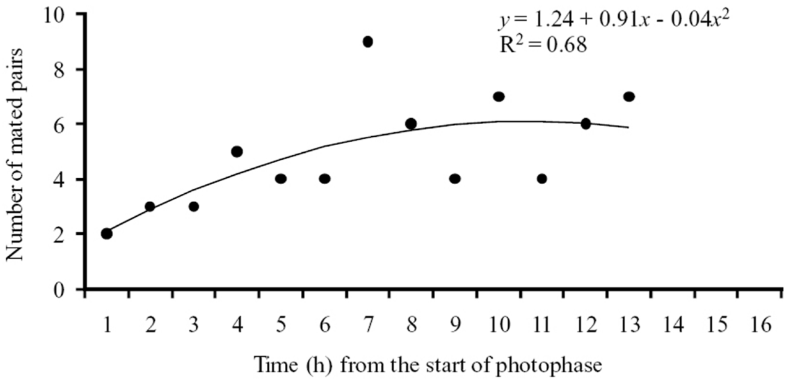

FIGURE 2: The number of *M. tasmaniae* pairs observed mating at various time points after the start of the photophase.

DISCUSSION

Lacewings are usually nocturnal. In green lacewing, *C. carnea*, emergence follows an endogenous circadian rhythm (Duelli 1980) and adult emergence from the cocoons occurs mainly at night, with a prominent peak in the first hour of the scotophase (Duelli 1980). However, results from the present study indicate that adult emergence peaked 3 h before the start of the scotophase. Because *M. tasmaniae* is a nocturnal predator, emergence of the adults some time before the scotophase starts possibly coincides with more favourable conditions, such as dusk, in which adults may increase the chance of locating a safe habitat or searching for prey.

Newly emerged Chrysopidae lacewings have immature gonads. They cannot mate and the females cannot oviposit (Canard & Principi 1984; Canard & Volkovich 2001). In certain lacewing species, e.g. *Chrysoperla congrua* (Walker) (Neuroptera: Chrysopidae), colour change may serve as a visual cue of sexual maturity used by conspecifics before initiating courtship (Winterson 1999). However, in the present study no such colour change was observed in *M. tasmaniae*. The present study showed that *M. tasmaniae* adults became sexually mature 2-3 days after emergence. In males, the reproductive output is closely linked with the number of females they are able to inseminate. Therefore, early maturity allows males better opportunities to find and mate with as many females as possible.

In lacewings, mating takes place when the oocytes are mature in the genital tract of the virgin female and oviposition of the inseminated female is initiated and stimulated by copulation (Rousset 1984). The females reach maturity in less than 3 days. In many species of Chrysopidae, the pre-oviposition period is 3-5 days (Canard & Principi 1984). The average longevity of a *M. tasmaniae* female is 2 months and she can lay eggs until she dies (A. Yadav, unpubl. data). Thus, the length of time required by females to become mature is not critical, as it may not significantly delay or reduce the reproductive opportunity during their life. Most of the mating occurred between 7 and 13 h after the start of the photophase, but no mating was observed 3 h before the scotophase began. Mating might last for 3 h. Thus, as nocturnal predators, this mating pattern would give considerable advantages to both sexes in undertaking host searching and/or oviposition after successful mating.

This study has provided the foundation for better manipulation of *M. tasmaniae* and future studies of reproductive behaviour of this predator. For example, newly emerged adults should be held for at least 3 days to ensure that copulation has occurred before they are released for biological control, and they may achieve a higher reproductive fitness and survivorship if they are released at night.

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