Using ultra-violet light traps to monitor autumn gum moth, *Mnesampela privata* (Lepidoptera: Geometridae), in south-eastern Australia

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Summary

Autumn gum moth (*Mnesampela privata* (Guenée)) is one of the most significant insect defoliators of plantation eucalypts in temperate Australia. Two 8 W ultra-violet light traps, able to sequentially sub-sample through time, were installed in a *Eucalyptus* plantation on the outskirts of Canberra, south-eastern Australia. Populations of *M. privata* were monitored from late November (end of spring) to the start of May (late autumn) in 1999/2000 and 2000/2001. Moth catches peaked during March of both trapping periods. The total number of moths trapped in each period was low (165 and 54, respectively). Female moths were rarely trapped (e.g. only 20 and 6 individuals in 1999/2000 and 2000/2001, respectively), but all had eggs. Most moths were caught between 0100 to 0430 h. Few moths were caught during the period up to 2130 h. At the time when most moths were trapped the minimum temperature was 10–18°C. More than 60% of moths were caught when the average wind speed was less than 1.0 m s^{-1}. There was a tendency for moths to be caught on dates a few days after the new or crescent moon, but before the first quarter. Trap catches a couple of days either side of the last quarter were also likely to be higher. The lowest temperature at which a male moth was trapped was 4.5°C; males were often caught when there was no wind. No females were trapped at temperatures lower than 15.2°C, and the lowest average wind speed at which female moths were caught was 0.8 m s^{-1}. To enhance the attractiveness to industry of light trapping for population surveillance of *M. privata* in plantations, concentrating trap deployment to nights in March and timing trapping to coincide with post-crescent but pre-first or pre-last quarter moon phases is recommended.

Keywords: monitoring; sampling; light traps; efficiency; pest control; *Mnesampela privata*; Australia

Introduction

Monitoring is a desirable ingredient in any population management strategy. For industries with small profit margins, for example, eucalypt plantation forestry, population monitoring that requires direct counts of particular insects by experienced field staff may not be economically viable if needed over large areas and/or for long periods (Clarke 1995). Under such circumstances alternative monitoring techniques that are less labour intensive may be more attractive (e.g. Clarke *et al*. 1998; Bashford 1999).

Ultra-violet light traps have long been used for monitoring populations of insects (e.g. Danthanarayana 1976; Muirhead-Thomson 1991). To enhance their likely application for population monitoring, the influence of environmental factors on the efficiency of the light trap must be known. This will enable nights to be chosen when the traps can be deployed to best advantage, thereby reducing ‘non-productive’ effort deploying light traps when no insects are likely to be caught. For example, wind speeds above 1.7 m s^{-1} suppressed the numbers of *Helicoverpa armigera* and, in particular, *H. punctigera* caught in light traps in cotton crops in the Namoi Valley (Morton *et al*. 1981). Furthermore, the optimal night-time temperature for catching these two moth species was 27°C; bright moonlight reduced the numbers of *H. armigera* by 49%, but had no apparent effect on catches of *H. punctigera* (Morton *et al*. 1981). Given such information, cotton growers might be recommended to trap for *H. armigera* and *H. punctigera* on still nights when the temperature is around 27°C. In the case of *H. armigera*, however, trapping would not be recommended on nights around the full moon, whereas for *H. punctigera* this stipulation is less important.

Another consideration when using light traps is that the amount of lunar illumination influences the efficacy of the trap. Light trap catches are inversely proportional to background illumination because the light from the trap becomes less apparent as the background illumination increases (e.g. on full-moon nights). The factors that influence the amount of lunar illumination and a relationship for standardising catches in relation to the amount of nocturnal illumination are considered in Bowden (1973, 1981, 1982, 1984) and Bowden and Church (1973).

Research on the biology, ecology and management of *Mnesampela privata* has significantly increased over the past decade because of heightened industry concern over the larvae’s potential to cause significant defoliation of newly planted trees. To date only a few studies are available on population monitoring of *M. privata* by means of light trapping (Table 1). Generally, because trapping has not been conducted for extended periods and/or because few environmental variables have been recorded when traps were operating, it is difficult to draw detailed conclusions from these data. It appears, however, that trap catches of *M. privata* are usually male biased and more moths are caught around the new moon than around full moon (Table 1). McQuillan *et al*. (1998) showed that catches in light traps of geometrid moths native to

Table 1. Summary of previous ultra-violet light trapping of *Mnesampela privata* studies conducted in south-eastern Australia

Location	Number, dates of trapping nights	No. of traps and globe wattage	Total catch of *M. privata*	Dates of peak catch	Male to female sex ratio	Lowest night-time temperature (°C)	Number of moths on new and full moons respectively	Author
Near Ringwood, Tasmania	10, Dec '80 –Feb '81	1 x 12 W	956	6 Jan '80 (291 moths)	13.4:1–2.3:1	2.0	326^{1}; 28^{2}	de Little, unpubl. data
Devonport, Tasmania	Weekly for '93–'95, '97, '99, '00	1 x 160 W	36.0 ('93) 40.0 ('94) 54.6 ('95) 29.3 ('97) 41.0 ('99) 40.0 ('00)	16–22 Apr '93 (9.0 moths*) 28 May–3 Jun '94 (4.6 moths*) 7–13 May '95 (9.3 moths*) 30 Apr–6 May '97 (6.0 moths*) 21–27 May '99 (12.0 moths*) 7–13 May '00 (18.7 moths*)	N/a	4.4† (Jun) 3.7† (Jul) 4.1† (Aug)	No details	Hill, unpubl. data
Near Surrey Hills, Tasmania	6, Nov '95 –Feb '96	1 x 8 W	11	14 Feb '95 (4 moths)	All male	0.6	No details	Lukacs 1999
Near Mildura, Victoria	10, Apr–Jun '98	1 x 8 W	1668 ('98)	1 May '98 (638 moths)	9.0:1–0.4:1 ('98)	2.9 ('98)	244^{3}; 85^{4} ('98)	Steinbauer *et al.* 2001‡ and unpubl. data ('02)
	60, Jan–Jun '99		6064 ('99)	15 Apr '99 (911 moths)	9.0:1–0.3:1 ('99)	7.0 ('99)	1363^{5}; 674^{6} ('99)	
	20, Mar–Jun '00		355 ('00)	29 Mar '00 (72 moths)	10.4:1–0.3:1 ('00)	6.0 ('00)	58^{7}; 40^{8} ('00)	
	No trapping '01							
	15, Apr–May '02		146 ('02)	29 Apr & 7 May '02 (24 moths)	11.0:1–0.9:1 ('02)	7.0 ('02)	79^{9}; 24^{10} ('02)	

Altitude (m asl) and annual rainfall (mm) for locations: Near Ringwood, 540 m and 1700 mm; Devonport, 70 m and 997 mm; near Surrey Hills, 600–640 m and 2204 mm; near Mildura, 42–54 m and 102–370 mm.

Key to numbering pertaining to numbers of moths and phase of moon: 1 = two new-moon nights; 2 = three full-moon nights; 3 = one new-moon night (day 1 of lunar cycle); 4 = one full-moon night (day 16 of lunar cycle); 5 = seven new-moon nights (days 0–2 and 28–29 of lunar cycle); 6 = seven full-moon nights (days 13–16 of lunar cycle); 7 = five new-moon nights (days 0–2 of lunar cycle); 8 = six full-moon nights (days 13–16 of lunar cycle); 9 = two new-moon nights (days 1–2 of lunar cycle) and 10 = one full-moon night (day 17 of lunar cycle).

*Data are average number of moths trapped per week.

†Temperatures represent 36-y average minima (for the nearest weather station) for the month when the latest trap catch was recorded.

‡Monthly averages only presented.

Eucalyptus forests in Tasmania increased with increasing minimum night-time temperature, but as *M. privata* was not amongst the species caught it was not possible to determine what influence night-time air temperature has upon the activity of the moth.

Light traps are currently the most labour-saving monitoring technique available to the eucalypt plantation industry. Though comparatively costly, at around AUD416 each (including a 12 V battery), light traps can be set up and left to operate for up to three nights without any maintenance. In day-to-day industry operations, however, light traps are seldom used to monitor *M. privata*, possibly because staff consider them too much effort (e.g. in terms of having to be deployed whenever required and because the trap catch must be sorted afterwards to count the numbers of *M. privata* caught). The present study sought to investigate the influence of various environmental variables on light trap catches of *M. privata*, the intention being to recommend nocturnal conditions when trapping is most likely to be effective. With such information, pulpwood plantation companies could deploy light traps more judiciously and thereby reduce surveillance costs associated with this and other means of population monitoring.

Materials and methods

Study insect

Mnesampela privata is endemic to south-eastern and south-western Australia (McQuillan 1985). Egg clutches can be laid any time from late summer to late autumn. Young larvae skeletonise leaves; later instar larvae produce leaf shelters in which they usually remain during daylight hours (Elliott and Bashford 1978; McQuillan 1985). Larvae pupate in the soil around the bases of tree trunks and may oversummer there (Lukacs 1999; Steinbauer *et al.* 2001). Moths begin to appear during mid-summer and can continue to emerge until early winter (Elliott and Bashford 1978). Both sexes are fully winged.

Study site, light traps and recording environmental variables

This study was undertaken in an experimental planting of 500 eucalypts of known species, subspecies and provenance identities. The plantation included *E. globulus* and all its subspecies, as well as *E. nitens*, all of which are susceptible to attack by *M. privata*. The plantation was located near Hall (New South Wales;

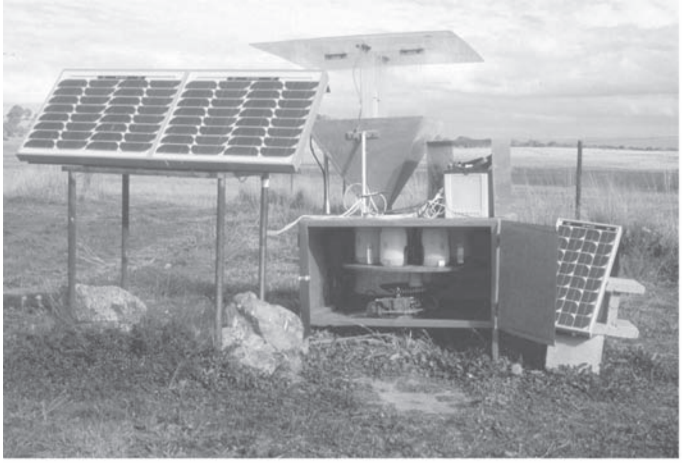

Figure 1. One of the light traps able to sequentially sub-sample though time by means of seven individual collecting bottles that rotate under the trap funnel at pre-programmed intervals.

35°09'55.7"S and 149°02'49.9"E; altitude 615 m asl) on the CSIRO Ginninderra Experiment Station. The trees were planted in October 1998 as 6-mo-old seedlings.

Figure 1 shows a light trap of the design used in this study. Each trap was fitted with an 8 W UV (i.e. ‘black light’) tube that was replaced regularly to ensure maximum illumination. A perspex roof was also placed over each tube and funnel to protect the electrical wiring and prevent rainwater from filling the collecting bottles. The collecting bottles sat on a circular shelf that rotated periodically during the night. Each collecting bottle was housed in a fixed, individual bottle-holder. This ensured that the bottles did not move and could be aligned precisely with the bottom of the trap funnel at each rotation. Before trapping commenced each bottle was filled with about 200 mL of soapy water. The timing and rotation of the collecting bottles were regulated by a single 24 V, EASY412-DC-RC control relay (Klöckner-Moeller GmbH, Bonn). Because mains electricity could not be used, the power for the control relay, lights and motors was collected during the day by means of two solar panels and stored in two 12 V car batteries. About 30 m of open ground separated the traps. This distance would have prevented the fields of illumination produced by each tube from coalescing at night (C. Szabadics, 1998, *pers. comm.*). Consequently, the illumination from each trap can be considered a discrete source of attraction for nocturnal insects. Each trap was separated from the nearest eucalypt by about 10 m of open ground.

The traps were programmed to produce illumination for the 12 h from 1800 to 0600 (EST). This period was divided into 7 sub-sampling times, corresponding to the number of collecting bottles. Collecting bottle 1 was under the trap funnel from 1800 to 1945 h, bottle 2 from 1945 to 2130 h, bottle 3 from 2130 to 2315 h, bottle 4 from 2315 to 0100 h, bottle 5 from 0100 to 0245 h, bottle 6 from 0245 to 0430 h and bottle 7 from 0430 to 0600 h. The time, as displayed by the Klöckner-Moeller GmbH control relay as well as by the portable data-logger (see below), was corrected to account for daylight saving.

Both traps were run almost continuously from 23 November 1999 till 2 June 2000 (interruptions were 20–27 April 2000 and traps were operated only on weekdays from 5 May till 2 June 2000). During 2000/2001, both traps were run almost continuously from 28 November 2000 till 1 June 2001 (interruptions were 30–31 January and 11–17 April 2001).

Light traps were inspected daily (except on most weekends) and the number of *M. privata* recorded. Moths were preserved in individual vials containing 70% ethanol. Fresh soapy water was then placed in each bottle before it was returned to its allocated bottle-holder.

A Starlog (UNIDATA Australia, Perth) portable data-logger (model 6003A), with version 3.09 software, was placed about mid-way between the two light traps. The data-logger was fitted with a model 6504-FS weather instrument for measuring wind speed (up to 35.7 m s^{-1}) and a model 6501EU ambient temperature sensor. From the commencement of this study until 14 February 2000 at 1500 h, the data-logger recorded wind speed and temperature maxima, minima and averages at intervals of 3 h. After this date the data-logger recorded at hourly intervals.

Dates for moon phases during the trapping periods were obtained from http://www.auslig.gov.au/geodesy/astro/moonphases/moonphases.htm. For the purposes of illustrating the data I took the lunar month to be 30 days. This period is based on rounding up from the duration of an actual lunar month, that is, 29.53 days (Bowden 1973). As no sensor to record nocturnal illumination was attached to the data-logger, it was not possible to use the relationship proposed by Bowden (1981) for standardising catches relative to background illumination. The inference that lunar illumination was greatest on full moon nights and lowest on new moon nights (not accounting for cloud cover) is based on Bowden (1973). Combining light trap catch data according to moon ages associated with similar lunar illumination is based on the example of Danthanarayana (1976, p. 69).

Data integration and analysis

Only trap catches from a single night’s trapping were correlated with data-logger records and data for moon age. Environmental records were assigned to trap catches thus: until the morning of 14 February 2000, bottles 1 and 2 were matched with data recorded at 2100 h (i.e. for the period 1800–2100 h); bottle 3 with 0000 h data; bottles 4 and 5 with 0300 h data and bottles 6 and 7 with 0600 h data. From the evening of 14 February 2000, catches in bottle 1 were matched with data recorded at 2000 h (i.e. for the period 1900–2000 h); bottle 2 with 2100 h data; bottle 3 with 2300 h data; bottle 4 with 0100 h data; bottle 5 with 0200 h data; bottle 6 with 0400 h data and bottle 7 with 0600 h data. The latter protocol was adopted for data for 2000/2001.

One-way ANOVAs were used to analyse differences between averages for monthly and time interval trap catches within years. For the data concerning trap catches in relation to temperature, wind speed and moon age/illumination I used ‘catch rate’ (after Morton *et al*. 1981, p. 210) to summarise trends. That is, a night’s catch rate is the number of moths caught as a proportion of the total moths caught throughout the trapping period. Chi-squared goodness of fit (for more than two categories) tests were used to

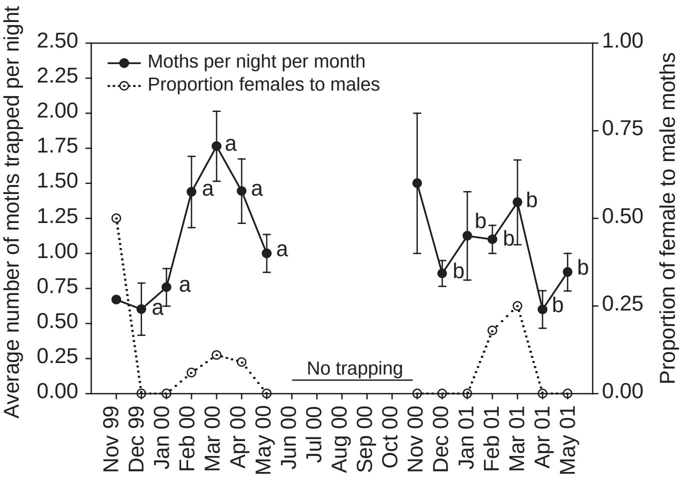

Figure 2. Monthly light trap catches (y1) of *Mnesampela privata* and sex ratios (y2). Monthly trap catch data are averages ± s.e. (n = 5, 8, 16, 29, 15 and 2 records for December 1999 to May 2000, respectively, and n = 6, 4, 10, 11, 6 and 5 records for December 2000 to May 2001, respectively). Monthly catch data for each trapping period were analysed separately using one-way ANOVA; within-period averages with the same letter are not significantly different ($F_{5,\,69} = 1.88$, $P = 0.11$ for 1999/2000 and $F_{5,\,36} = 1.51$, $P = 0.21$ for 2000/2001).

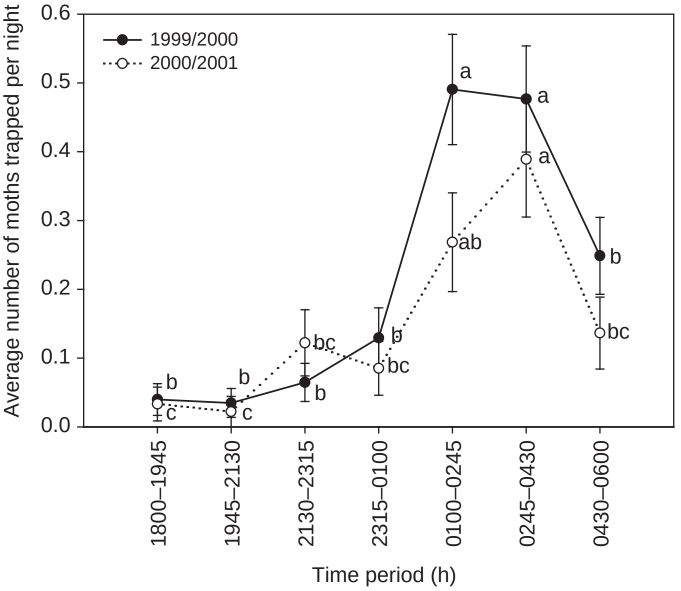

Figure 3. Time interval light trap catches of *Mnesampela privata*. Time interval catch data are averages ± s.e. (n = 67 and 63 records each for 1800–1945 to 0100–0430 and 0245–0430 to 0430–0600, respectively, in 1999/2000 and n = 45 and 44 records each for 1800–1945 to 0245–0430 and 0430–0600, respectively, in 2000/2001). Time interval catch data for each trapping period were analysed separately using one-way ANOVA; within-period averages with the same letter are not significantly different ($F_{6,\,454} = 14.85$, $P < 0.001$ for 1999/2000 and $F_{6,\,307} = 6.25$, $P < 0.001$ for 2000/2001).

determine whether trends in these data were non-uniform. Two-sample *t*-tests assuming unequal variances and using two-tail critical values for *t* were used to examine differences between dry body weights according to sex of moths caught in each trapping period. Linear regressions were used to examine whether the body weights of moths and the temperatures and wind speeds at which they were caught exhibited significant correlations with one another. Analyses were conducted using MINITAB.

Results

Seasonal, monthly and time interval trap catches

The total trap catch for 1999/2000 was three times as large as that for 2000/2001 (i.e. 165 versus 54 moths). In both trapping periods, the sex ratios of trapped moths were male-biased (Fig. 2). This tendency was particularly prominent during the months when moth activity was greatest, i.e. February to March. In 1999/2000 female moths represented 12.1% of the total catch and in 2000/2001 females represented 11.1% of the total catch. In all instances, the trapped females had eggs.

There was a general increase in the numbers of moths caught per night in the months leading up to March in both periods (ignoring data for November 1999 and 2000). Thereafter, the numbers of moths caught per night declined (Fig. 2). Due to the variation in the data, monthly trap catches within each period were not significantly different from one another.

There were statistically significant differences between the average numbers of moths caught per night according to time interval (Fig. 3). In 1999/2000, most moths were caught between the hours of 0100 and 0430. In 2000/2001, most moths were caught between 0245 and 0430 h. For both trapping periods, the fewest moths were caught between the hours of 1800 and 2130.

Temperature, wind speed, moon age, moon illumination and trap catches

In 1999/2000 and 2000/2001, in the months when most moths were caught, the temperature range was 10–18°C (Fig. 4A). A chi-squared goodness of fit test based on temperature interval, and using counts of individuals from 1999/2000, indicated that the data exhibit significant non-uniformity ($\chi^2 = 112.3$, $n = 11$, $P < 0.001$). There was a similar result for the data from 2000/2001 ($\chi^2 = 42.0$, $n = 11$, $P < 0.001$).

There was a rapid decline in the catch rate of *M. privata* as wind speed intervals increased from 0.0–0.5 m s^{-1} to 1.0–1.5 m s^{-1} in both 1999/2000 and 2000/2001 (Fig. 4B). A chi-squared goodness of fit test based on wind speed interval and using counts of individuals from 1999/2000 indicated that the data exhibit significant non-uniformity ($\chi^2 = 113.9$, $n = 8$, $P < 0.001$). There was a similar result for the data from 2000/2001 ($\chi^2 = 68.6$, $n = 8$, $P < 0.001$).

The trap catch rate for *M. privata* generally declined with increasing moon age until a few days after the full moon and generally rose again thereafter until two or three days prior to the new moon (Fig. 5A). I chose not to conduct any statistical analyses on these data, preferring to examine trends pertaining to the comparative amounts of lunar illumination associated with given

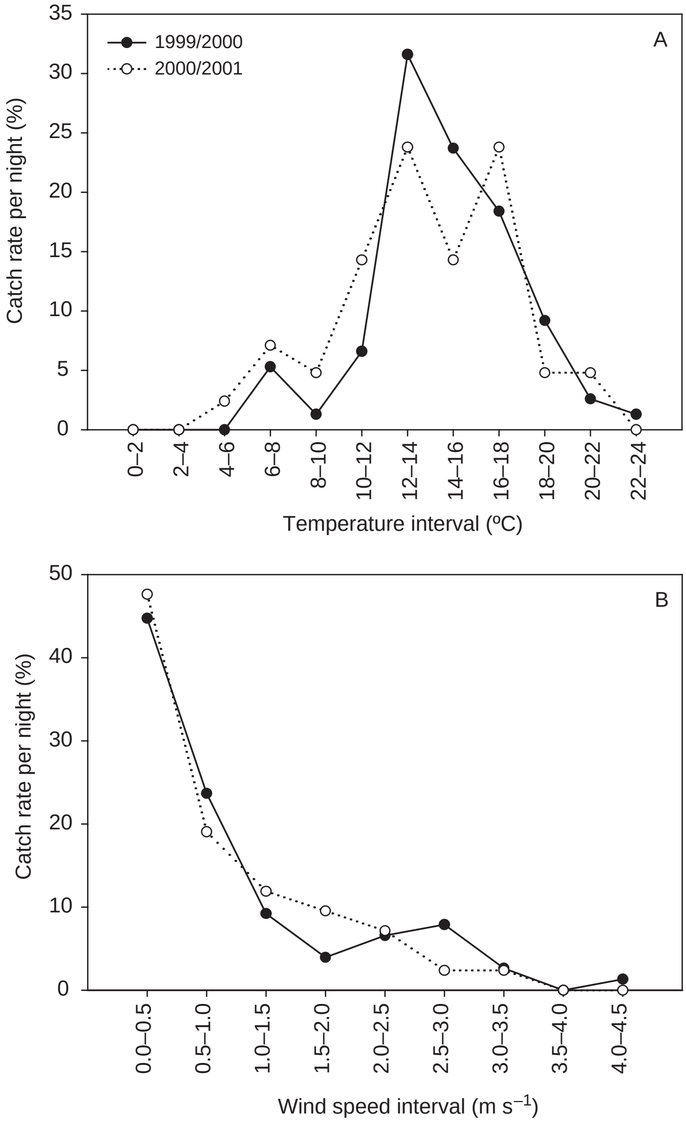

Figure 4. Temperature and wind speed intervals in relation to trap catch rates for *Mnesampela privata*. Results of chi-squared goodness of fit tests are presented in the text (tests were performed using count rather than percentage data).

moon age. For example, in 1999/2000 the numbers of individuals caught was low at the time of the new moon, rose to a peak after the crescent moon and then declined for all other comparable lunar illumination periods until the full moon (Fig. 5B). This trend exhibited significant non-uniformity ($\chi^2 = 52.9$, $n = 7$, $P < 0.001$). A similar pattern of counts of moths was obtained in 2000/2001. The non-uniform trend in this data was also significant ($\chi^2 = 16.2$, $n = 7$, $P < 0.01$).

Seasonal variation in body weight and the influence of temperature and wind speed on trap catches

Male moths typically weighed less than female moths irrespective of season or year of trapping (Table 2). Male moths caught in summer 1999/2000 did not weigh significantly more than males caught in autumn of 1999/2000 (Table 2). The findings were similar for female moths caught in summer versus autumn 1999/2000 as well as for male and female moths caught in summer versus autumn 2000/2001. When the dry weights of male moths caught in 1999/2000 were combined and compared with those caught in 2000/2001, the former were found to weigh significantly less than the latter (e.g. 15.0 ± 0.2 mg versus 16.5 ± 0.4 mg, respectively, $t_{79} = 3.09$, $t_{0.05} = 1.99$, $P = 0.003$). The finding was similar for female moths from 1999/2000 versus 2000/2001 (e.g. 25.3 ± 2.2 mg versus 34.1 ± 2.2 mg, respectively, $t_{16} = 2.76$, $t_{0.05} = 2.12$, $P = 0.01$).

No correlations between dry body weight of male or female moths and minimum temperature or average wind speed were apparent. The lowest temperature at which a male moth was trapped was 4.5°C. No females were trapped at temperatures lower than 15.2°C. Males were often caught when there was no wind, whilst the lowest average wind speed at which female moths were caught was 0.8 m s^{-1}.

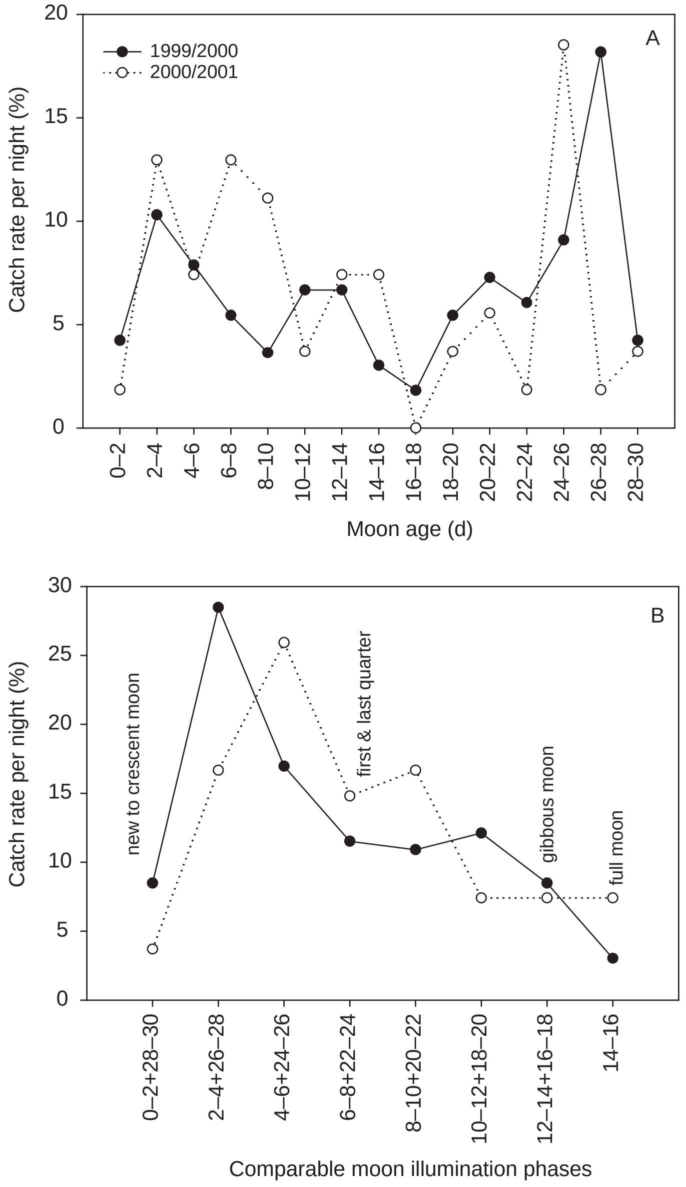

Figure 5. Moon ages and illumination phases in relation to trap catch rates for *Mnesampela privata*. Results of chi-squared goodness of fit tests are presented in the text (tests were performed using count rather than percentage data).

Table 2. Summary of dry weights (mg) of male and female *Mnesampela privata* adults caught in summer and autumn in 1999/2000 and 2000/2001. Data are means ± s.e. (no same sex, same trapping period, different season comparisons were statistically significant (two-sample *t*-tests)).

Period	Summer		Autumn	
	Males	Females	Males	Females
1999/2000	15.4 ± 0.4 *n* = 45	26.0 ± 4.1 *n* = 7	14.9 ± 0.3 *n* = 100	25.0 ± 2.7 *n* = 13
2000/2001	16.0 ± 0.5 *n* = 25	31.8 ± 6.9 *n* = 2	17.1 ± 0.6 *n* = 23	35.2 ± 1.9 *n* = 4

Discussion

With the exception of the trapping conducted in Devonport, Tasmania (Table 1), this study represents the most comprehensive light trapping for *M. privata* yet undertaken. Of the studies summarised in Table 1, only this study has set out to quantify how catches of *M. privata* will vary with some of the environmental variables known to be important to the flight activities of other moth species.

There are two findings in common between this work and the studies in Table 1. First, typical light trap catches are male biased. Often there are ten times the number of male to female *M. privata* caught on any one night of trapping. Male-biased sex ratios in trap catches (but not necessarily in the population) are not unusual. Typically, females are widely dispersed and males must seek them out in order to mate. It is for this reason that males may be most often caught in traps and, as a result, experience higher rates of natural mortality (Gwynne 1987). Female *M. privata* are not as strong fliers as males, possibly because of their greater body weight (M.J. Steinbauer *pers. obs*.). Furthermore, female *M. privata* may fly only under specific conditions. For example, Steinbauer *et al*. (2001) reported catching a lone female in a 20 W light trap situated some 224 m distant from the nearest oviposition host (and 4.5 m above the ground). It is possible that this female was dispersing to search for oviposition or food (e.g. honeydew) resources. Dispersal by *M. privata* requires considerably more investigation as it is the prime factor determining the colonisation of new plantations.

Second, light trap catches are typically reduced on full moon nights. This is a relatively common finding from other studies (e.g. *H. armigera* in Morton *et al*. 1981; references in Muirhead-Thomson 1991). It is not, however, the case for all moth species (*Epiphyas postvittana* (Walker) in Danthanarayana 1976; *H. punctigera* in Morton *et al*. 1981). The response of *Mnesampela privata* to moonlight provides an interesting contrast to that of *E. postvittana*. Specifically, trap catches of *M. privata* are likely to be reduced on full moon nights whereas those of *E. postvittana* are likely to be as high as those on new moon nights, whilst catches of *M. privata* are likely to peak just before the first or last quarter, and those of *E. postvittana* are likely to be at their lowest just after the first or last quarter.

In each year of this study, trap catches of *M. privata* peaked in March. Only the trapping conducted in Devonport has also spanned both summer and autumn of the years in which it was conducted (Table 1). In Devonport, the numbers of *M. privata* peaked in either April or May. By April of 1999/2000 and 2000/2001, trap catches of *M. privata* in Canberra had started to decline. These differences provide further evidence of the plasticity in seasonal phenology that *M. privata* exhibits — as was considered at length by Lukacs (1999). This plasticity is achieved through a pupal diapause (during winter and spring) that may or may not be also associated with a summer aestivation-type response. It is the interplay between these two mechanisms that may or may not result in summer activity. The timing of emergence dictates when moths are active and, therefore, the night-time temperatures at which moths are caught (discussed further below). This study also revealed that *M. privata* is most likely to be caught at light traps after 0100 h but before 0430 h. What portion of this behaviour is due to changes in the amount of lunar illumination (due to position of the moon or cloud cover) and/or ambient temperature (or some other environmental variable, such as relative humidity) at such times remains to be investigated further.

This study has also provided the first detailed information on light trap catches of *M. privata* in relation to minimum ambient temperature and average minimum wind speed. Most *M. privata* were trapped when the minimum temperature was 10–18°C. The lowest temperature at which a male moth was caught, however, was 4.5°C, whilst the lowest temperature for a female was 15.2°C. It is reported that some species of moth have activity threshold temperatures. For example, the temperature threshold for activity for *Cydia pomonella* (L.) is 12–15°C (reference cited in Geier 1981). Currently there does not seem to be any indication of the temperature threshold for activity in *M. privata*. Specifically, during trapping at a locality near Surrey Hills, Tasmania, the lowest temperature at which *M. privata* was caught was 0.6°C (Lukacs 1999 in Table 1). Furthermore, my data for body weights versus temperatures do not show any correlations, such as those shown by McQuillan *et al*. (1998). Consequently, it is not possible to extrapolate back to determine a species-specific threshold temperature for flight. It appears that moths must fly at whatever ambient temperatures are prevalent in order to locate a host and/or a mate. What is somewhat more evident is that trap catches of *M. privata* will be reduced at wind speeds above 1.0–1.5 m s^{-1}.

The primary aim of this study was to recommend ways in which monitoring of *M. privata* by light traps might be made more cost-effective. My findings indicate that there is little point light-trapping on nights when it is likely that strong winds will persist throughout the night. Furthermore, trapping should take place on nights just after a crescent moon, but before the first quarter or just prior to the last quarter, in particular during March.

In addition, staff should ensure that each trap has sufficient power to provide the maximum possible illumination throughout the night as most moths are likely to be caught many hours after dusk. Bowden (1981) discussed how the following equation explained light trap catches of nocturnal insects:

$$\text{catch} = \text{constant}\ (W^{0.5} / I)\ ,$$

where W = trap illumination and I = background illumination. This model suggests that increasing the illumination of the trap will provide a stronger source of attraction for a given background (lunar) level of illumination. Hence, it is likely that the use of traps with higher-rated globes will increase trap catches (although there will be some upper limit to this effect). The trap data from Devonport in Table 1 may support this suggestion in that this light trap was not operated in a commercial eucalypt plantation and, as a consequence, the *M. privata* caught in it may have been attracted from further away than was the case in the trapping undertaken in this study.

Outbreaks of *M. privata* will continue to occur sporadically throughout the moth's region of endemism so long as large areas of eucalypts of the same genotype and age are planted in close proximity to one another (Steinbauer and Floyd 2001). Early detection of the colonisation of newly established *E. globulus* and *E. nitens* plantations by *M. privata* is essential. That is, *M. privata* is constrained by the availability of juvenile foliage and the time required for the populations of adults to increase sufficiently for them to lay economically damaging numbers of eggs (determined by the size of the tree) on a large proportion of the trees in a single plantation. Female moths prefer not to lay eggs on adult foliage and it is probably partially for this reason that populations of the moth decline after phase change (Steinbauer 2002). Should colonisation of a plantation by *M. privata* be detected during the first season after establishment, the need for more intensive light trapping will be greater in following seasons because the probability of an outbreak will be increased. Hence, the role of routine light trapping should be to assist with the timing of control operations. What has yet to be determined is the relationship between the numbers of moths in a light trap and the level of defoliation that is likely to occur to the trees. For example, the numbers of moths in a light trap that should warrant concern in the case of a newly established plantation is likely to be lower than the numbers in a light trap in a plantation in its last year of juvenile foliage.

In order to compare insect populations in different plantations and in different years it is essential to have a sampling technique that remains constant even though staff and company management may change. For example, counts of insect life stages per plant module and damage ratings will vary according to the protocols adopted by a company and the operators making the observations. In contrast, a light trap will function independent of an operator and attract whatever moths are within its area of illumination. It is for these reasons that light trap counts of *M. privata* offer better prospects of obtaining reliable and unbiased population data. Only through the use of reliable population data will risk prediction and management at the plantation and region-wide scales be possible. I hope that these arguments provide strong incentive for the increased adoption of routine light trapping for monitoring populations of *M. privata*.

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