Journal of the Lepidopterists' Society
33(4), 1979, 232–238

DAILY FLIGHT PERIODS OF MALE *CALLOSAMIA PROMETHEA* (SATURNIIDAE)[1]

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ABSTRACT. Flight periods of male *Callosamia promethea* were determined by marking their positions in a large flight cage at hourly intervals from 0800 to 2000, and recording the number in flight and the number moving from previous positions. Nocturnal flight activity was determined by marking male positions ca. 1 h after sunset and again at sunrise. Flight activity occurs from 7 h before to 1 h after sunset and peaks 5–2 h before sunset. Preliminary observations of female pheromone release indicate that pheromone release is synchronous with male flight activity, and peaks 4–1 h before sunset. Pheromonal stimulation may be an important component in initiation of male flight activity.

It has long been known that males of *Callosamia promethea* (Drury) are attracted to females by a pheromone during the afternoon, usually between 1400 and sunset (e.g. Ferguson, 1972; Collins & Weast, 1961; Eliot & Soule, 1902; Mayer, 1900). Rau & Rau (1929) attempted to quantify the flight period of *promethea* by releasing both bred and wild caught numbered males at various distances from caged females and noting the time of arrival of males. They found a peak of activity from 1600–1640 Central Standard Time at St. Louis, Missouri, with 14 of 33 recaptured males returning during this period. They also observed one male arriving at dawn with males of *Hyalophora cecropia* (L.), though they did not state to which species (female *cecropia* or female *promethea*) the *promethea* male was attracted. In all of the above work, male flight periods were apparently determined by watching caged females and observing time of male arrivals. Thus, these observations do not establish conclusively that flight activity of male *promethea* is limited to the afternoon. This aspect of behavior can be determined only be watching males throughout the day.

Because of our studies on mimicry, involving the release and recapture of variously painted *promethea* males (Waldbauer & Sternburg, 1973; Sternburg et al., 1977), it became necessary to define more precisely the flight activity of males. If male *promethea* were nocturnal as well as diurnal, nocturnal predators could account for the differential recapture of mimetic vs. non-mimetic color patterns observed by Sternburg et al. (1977). The non-mimetic yellow pattern

[1] Part of the Ph.D. dissertation presented by the first author to the Department of Entomology, University of Illinois.

may be more conspicuous at night than the black mimetic pattern. If males fly only in the afternoon, then exposure to diurnal predators will be less than if males were to fly in both the morning and afternoon.

MATERIALS AND METHODS

We used freshly emerged male and female *promethea* reared on wild black cherry (*Prunus serotina* Ehrh.) or tuliptree (*Liriodendron tulipifera* L.) at Urbana, Illinois. Adults emerged from pupae allowed to overwinter in an outdoor insectary. These stocks originated from wild populations from the vicinity of Charleston, Illinois or Medaryville, Indiana.

Males were individually distinguished by white numbers painted on the ventral surface of the hindwings. They were released into a flight cage (2.36 m × 1.83 m × 2.36 m) containing a wild black cherry tree (ca. 1.8 m tall) and a recording thermograph. They were observed, their positions marked, and the number in flight (if any) noted at hourly intervals from 0800 to 2000 (all times Central Daylight time) each day from 8 to 11 July 1977. There were 16 males in the cage on 8, 10, 11 July, and 15 males on 9 July. New males were added to the cage at 1100 on 10 and 11 July. They were allowed to settle; then their positions were marked. At the next hourly observation, their positions were noted along with the positions of males which had been present all day. Only one of the 15 males added to the cage this way moved during that hour. This four-day intensive observation period was supplemented by less regular observations from 3 June to 8 July that are not included in the table.

Night activity in 1977 was determined by mapping the positions of males at sunset and again at sunrise. When it was found that no movement took place between sunrise and 0900, the morning observations were changed to between 0700 and 0900. These observations were made on eight nights in June, 1977, using a total of 115 males. Because a higher percentage of these males moved at some time during the night than expected (22.8%), nighttime observations were repeated in 1978.

The flight cage was moved to a new location over a small, dense, low-growing barberry (*Berberis*) cultivar in an effort to provide males with sheltered resting sites. However, most males continued to rest on the sides and top of the cage (see below) rather than in vegetation. Male positions were marked between 2100 and 2200 and again between 0500 and 0600 the following day. Sixty-two observations on 30 males were made between 29–31 May and between 5–7 June 1978.

RESULTS AND DISCUSSION

Table 1 shows that most diurnal flight activity of male *promethea* occurs during the afternoon between 1300 and 2000. The peak of activity occurs from 1600 to 1700, 4 to 3 h before sunset. There is some activity in the morning, but we believe this may be an artifact of confinement in the flight cage. The natural resting site of wild males is presumed to be in vegetation, but they often rested on the sides or top of our cage. For example, on the morning of 8 July, 13 of 16 males were resting on the sides or top of the cage and not in the tree. Seven of these 13 males moved during the period 1000–1100 (70% of all males moving during these hours on all four days). Of those moths moving, three moved 0.3 m or less. Of the four remaining males, three moved from exposed positions on the top of the cage to sheltered positions on the cage sides, while the fourth male moved from an exposed position on one side to a sheltered position on another side. We believe that males which moved in the morning were shifting from positions exposed to the sun, possibly to avoid increasing temperatures. On 8 July, when most of these males moved, the temperature reached 31.1°C at 1400, the highest recorded for the four-day period, and was already 29.4°C at 1100. During the period 1000–1100, 8 July, the temperature rose 2.8°C, the largest increase in temperature in one hour during the period 0800–1100 on any of the four days. The maximum temperature for the other three days during the period 0800–1100 was 27.2°C, while the largest hourly increase in temperature was 2.2°C. Other morning movements were similar in that males moved from exposed to sheltered positions, although not all males in exposed positions moved. None of the males which rested in the tree (five males over four days) moved before 1400. Only three males were observed to fly in the morning, one because it had been disturbed (Table 1). Males were observed in flight primarily at 1600 and 1700, corresponding well with the number of males observed to change their positions.

In 1977, 23 of the 115 males observed to determine nocturnal movements were eliminated from the data: 11 because they could not be found at sunset to mark their positions, one because it flew to an unknown location when it was disturbed as its position was marked, and 11 because they died during the night. Of the remaining 92 males, 21 (22.8%) moved during the night. This is a higher percentage of movement than expected. The 1978 observations indicate that this high percentage was the result of marking male positions too early in the evening. In 1977, male positions were marked at sunset, which occurs shortly after 2000 in Urbana at the time of year these obser-

TABLE 1. Diurnal movements of male *Callosamia promethea* (Drury) in a flight cage by time of day on 4 days. The table includes 63 observations per hour on 31 different males.

	Hour of observation												
	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
Number of males changing position (n)	0	0	0	10	5	3	15	18	47	59	45	31	12
% of males changing position (n/63 × 100)	0	0	0	15.9	7.9	4.8	23.8	28.6	74.6	93.6	71.4	49.2	19.0
Number of males in flight (n)	0	1	0	2	0	2	7	7	30	15	8	3	1
% of males in flight (n/63 × 100)	0	1.6	0	3.2	0	3.2	11.1	11.1	47.6	23.8	12.7	4.8	1.6

vations were made. Table 1 shows that nearly 20% of males moved between 1900 and 2000. In 1978, male positions were marked between 2100 and 2200, approximately one hour after sunset. When this was done, only two males (3.2%) were observed to move during the night. Both of these males exhibited wing fluttering behavior when their night positions were first marked, and did not fold their wings and rest quietly during the 20 to 30 minute period required to mark all male positions. Thus it seems likely that these two males moved shortly after we left the flight cage for the night.

Preliminary observations of virgin female *promethea* indicate that peak flight activity of males corresponds roughly to peak pheromone release by females. Sixty-eight females were watched in the early afternoons of 16, 29, 30 June and 1, 5, and 6 July for extrusion of an abdominal gland, which, on the basis of male behavior, is obviously the source of the sex pheromone. Females began extruding this gland between 1400 and 1500 (three females) and by 1700, 59 of the 68 females had extruded it. Of the remaining nine females, eight extended the gland during the next hour; while one had not extruded her gland by 1800 when observations ceased. Observations of some of these and of other females during the morning and early afternoon (before 1400) indicated that the abdominal gland is never extended between 0800 and 1300. Thirty-three females were watched on the evenings of 14, 15, 16 and 22 June to observe times of retraction of the abdominal gland. One female retracted the gland between 1800 and 1900, 12 retracted it between 1900 and 2000, and 20 retracted it between 2000 and 2100. At this time of year sunset occurs at Urbana between 2023 and 2026. Thus, female *promethea* stop releasing pheromone before twilight ends. To make sure nocturnal release did not occur, 12 females were watched all night on 22 June. Observations were made hourly up to 2200, and every 2 hours thereafter until 0600, 23 June. Females were observed with a flashlight covered by a red cloth to minimize disturbance. At no time did any of them extrude their abdominal glands.

Collins & Weast (1961) noted that certain atmospheric conditions could cause males to fly as early as 1300. Their times are presumably standard times, while ours are daylight times; thus our 1400 corresponds to their 1300. We noted that females tended to extrude their glands earlier on cloudy days, but did not make enough observations under appropriate conditions to quantify this.

Skinner (1914) found that male *Callosamia angulifera* (Walker) were attracted to female *C. promethea* between 2000 and 2100. In the course of our release-recapture experiments with painted male *promethea* in Urbana, we attracted a male *C. angulifera* with a female

promethea sometime between 1930 8 August and 1900 9 August, 1977, and another male *angulifera* sometime between 1300 12 June and 1900 13 June, 1978. Ferguson (1972) notes that female C. *angulifera* attract males between dusk and midnight, with a peak activity at 2200. The slight overlap of *promethea* pheromone release and *angulifera* flight activity may account for this interspecific attraction. The three species of *Callosamia* appear to be reproductively isolated by their differing pheromone release and male flight periods (Ferguson 1972) but the ability to attract males of one species with females of another indicates that this isolating mechanism occasionally breaks down.

Brown (1972) suggested that males of *Callosamia securifera* (Maassen) did not need a pheromone stimulus to start flight activity, which occurs from 1000 until 1500 in this species. Our observations indicate that pheromonal stimulation may be a component of flight initiation in *promethea:* For example, on 9 June at 1425, 10 males were in the flight cage in the same positions they had occupied since 0940 that morning. Two females were in a cage upwind close by and neither had been observed to extrude the abdominal glands all day. Between 1425 and 1435 most of the males began quivering, a characteristic behavior exhibited immediately before afternoon flights, and four males actually flew. We then checked the female cage and found that one female was extruding her abdominal gland. The second female extruded her gland 10 min. later. By 1500, all but 2 of the males had flown. By moving female cages downwind, we could often cause males in the flight cage to settle. No experiments were tried where females were absent to see if males would fly without pheromonal stimulation, as the area in which the flight cage was located possesses a wild population of *promethea* and the possibility of stimulation by a wild female could not be excluded.

Other work by Jeffords, Sternburg and Waldbauer (in prep.) indicates that male *promethea* do fly in the afternoon without pheromonal stimulation. They released painted males of *promethea* at Allerton Park, Piatt Co., Illinois, where either no or a very small wild population of *promethea* exists, and then recaptured these males one day later in traps baited with virgin females. Wing damage analysis and the ratio of mimetic to non-mimetic painted male recaptures indicated that these males had flown the previous day when no females were present. However, the possibility of stimulation by wild females cannot be entirely discounted.

CONCLUSIONS

Male *promethea* are diurnal fliers, with a peak activity between

1500 and 1800, or between 5 and 2 h before sunset. The slight amount of morning movement is believed to be an artifact of confinement in a flight cage. Nocturnal movement does occur, but it is limited to a period less than 2 h after sunset and is thus more appropriately considered crepuscular. Thus males are exposed in flight to predators mainly in the afternoon.

Female sex pheromone release is apparently confined to the afternoon between 1400 and 2100 and peaks between 1600 and 1900 (4 to 1 h before sunset). No nocturnal or morning release, as evidenced by extrusion of the abdominal gland, was noted. Male flight activity may be initiated by reception of the female pheromone, and/or it may be the result of endogenous rhythms or other environmental stimuli.

ACKNOWLEDGMENTS

We thank Dr. C. T. Maier for the use of the flight cage, and Dr. W. H. Luckmann and the Illinois Natural History Survey for the use of the experimental area and facilities for rearing *promethea*. This work was supported by NSF Grant DEB 76-18618 to Waldbauer and Sternburg.

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