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DIAPAUSE AND EMERGENCE PATTERNS IN UNIVOLTINE AND BIVOLTINE POPULATIONS OF PROMETHEA (LEPIDOPTERA: SATURNIIDAE)

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ABSTRACT

Data are presented on the diapause and the seasonal emergence patterns of the adults of a univoltine *Callosamia promethea* population from northern Indiana and a partially bivoltine population from central Illinois. At Urbana, Illinois, the median emergence date of adults from overwintering Illinois pupae was about a month earlier than that of adults from overwintering Indiana pupae. Illinois samples had a much longer emergence period than Indiana samples. Indiana samples showed a slight tendency toward a bimodal emergence pattern, a few individuals emerging in late May and the rest emerging as a tightly synchronized group from late June to mid-July. Early emerging Illinois moths produced mostly non-diapausing progeny, but the proportion of diapausing progeny increased as the season progressed. Some females produced both diapausing and non-diapausing progeny. Adults emerged from non-diapausing pupae from early August to early September.

The promethea moth, *Callosamia promethea* (Drury) (Lepidoptera: Saturniidae), overwinters as a pupa in a conspicuous cocoon that hangs from a twig of the host tree or shrub. It is one of the most abundant and commonly collected saturniids of eastern North America, but surprisingly little information on its biology has been published, and few quantitative data on its voltinism or on the seasonal pattern of adult eclosion are available. Ferguson (1972) cited a few published accounts and personal communications which indicate that promethea is univoltine in the northern part of its range (Michigan and most of New England), possibly bivoltine in Rhode Island and New York, and certainly at least partially bivoltine from southern New Jersey and St. Louis, Missouri, south. Worth (1970) found it to be partially bivoltine in Cape May County, New Jersey, and noted that one overwintered female can produce both diapausing and non-diapausing progeny. Rau and Rau (1912, 1914) presented data on the emergence in the vicinity of St. Louis, Missouri, of promethea from native cocoons and cocoons from the vicinity of Fall River, Massachusetts.

We present data on the diapause and adult seasonal emergence patterns of a univoltine promethea population from northern Indiana and of a partially bivoltine population from central Illinois, which are separated by no more than 175 km and 1° 18′ of latitude.

MATERIALS AND METHODS

Cocoons were collected from young sassafras (*Sassafras albidum* (Nutt.) Nees) or black cherry (*Prunus serotina* Ehrh.) trees near the following towns in the months indicated: Medaryville, Indiana (41°4′ N latitude): March 1969, 1972, and 1973, December 1969, January 1974, and February 1975; Reynolds, Indiana (40°46′): March 1972; Charleston, Illinois (39°28′): April 1970 and 1974, March 1972 and 1975, and January 1973. The cocoons were then held at Urbana, Illinois (40°6′) in a screened

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outdoor insectary and checked daily for adult emergence from late April until emergence ended in July.

The adults probably did not emerge from cocoons held at Urbana on the same dates they would have in their native areas. However, moving the cocoons to an intermediate area (Urbana), where all cocoons experienced identical weather conditions, had the advantage of revealing inherent differences in the seasonal responses of the Medaryville and Charleston populations without the complicating effects of differences in weather. The emergence of these two populations at Urbana differed in every year of the study and was always characteristic of their geographic strain. Moreover, pupae of the Medaryville and Charleston strains that had been reared at Urbana produced adults in synchrony with pupae that had been wild-collected in those areas.

The Medaryville and Charleston samples of 1970 and 1972 were tested by chi-square analysis (1 d.f. continuity corrected) for differences in the seasonal distribution of emerging adults. A common median emergence date was determined by combining the two samples. A 2×2 contingency table was then constructed on the basis of the number of individuals from each area that emerged before or after this common median date.

In 1970 and 1973 to 1975 some of the females that emerged from wild Medaryville or Charleston cocoons were paired with males from the same locality. (More information on these pairings appears in Table 1, Fig. 3, and the text.) Their progeny were reared outdoors under nylon mesh sleeves covering black cherry saplings. The resulting cocoons were held in cages in the insectary and checked daily for adult emergence. After emergence stopped in September the remaining cocoons were examined to eliminate dead individuals. Heavy, non-rattling cocoons were assumed to contain diapausing pupae, a judgement confirmed by the emergence of adults from the great majority of these cocoons the following summer.

RESULTS AND DISCUSSION

On the whole, adults emerged from overwintering northern Medaryville cocoons much later than from overwintering southern Charleston cocoons. The median emergence dates at Urbana for samples from these two areas were significantly different in both 1970 (Figs. 1 and 2) and 1972 (Fig. 2) (for 1970 $x^2 = 13.0$ and $p < 0.005$; for 1972 $x^2 = 57.8$ and $p < 0.005$).

There was a slight tendency toward a bimodal emergence pattern in the Medaryville population (Figs. 1 and 2, Table 1), with adults of the early mode, seen only in 1969 and 1970 when the Medaryville collections were exceptionally large, emerging from mid- to late May (Fig. 1, Table 1). The adults of the late mode constituted about 99% of the emergence and had median emergence dates that ranged from 30 June in 1970 to 11 July in 1972 (Table 1). The late mode was tightly synchronized (Figs. 1 and 2), encompassing a mean of only 27.3 days over six years and ranging from 21 days in 1969 to 33 days in 1975 (Table 1). Promethea from Reynolds (34 km south of Medaryville) were available only in 1972; they emerged in synchrony with the Medaryville adults of that year (Fig. 2).

Adults of the Charleston population had median emergence dates that ranged from 30 May in 1970 to 15 June in 1975 (Fig. 2), about one month earlier than the Medaryville adults. The emergence pattern of the Charleston samples varied, but was almost always much more extended than that of the Medaryville samples. During five years the entire emergence period encompassed a mean of 47.8 days. In 1970 and 1972 it encompassed 59 and 66 days, respectively, but from 1973 to 1975 only 39, 32 and 43 days, respectively (Fig. 2). The duration of the emergence period appears to be inversely correlated with the mean temperatures for May and June, but this correlation cannot be shown to be significant on the basis of the available data.

The voltinism of the two promethea populations was determined by rearing at Urbana the progeny of some wild-collected adults of the Medaryville late emergence mode and the progeny of some wild-collected adults that represented almost the entire emergence period of the Charleston sample. In all four years that we made these rearings the Charleston population was partially bivoltine. The Medaryville population, at least as

Table 1. Emergence of adult promethea from cocoons collected near Medaryville and transferred to a screened outdoor insectary at Urbana, Illinois.

	First Emergence Group			Second Emergence Group		
Year	Number Emerging	Emergence Dates: Inclusive	Median	Number Emerging	Emergence Dates: Inclusive	Median
1969	1	31/5	31/5	260	26/6–16/7	5/7
1970	10	19/5–26/5	22/5	555	17/6–14/7	30/6
1972	0	—	—	61	20/6–19/7	11/7
1973	0	—	—	83	21/6–14/7	9/7
1974	0	—	—	65	21/6–18/7	9/7
1975	0	—	—	50	25/6–28/7	1/7

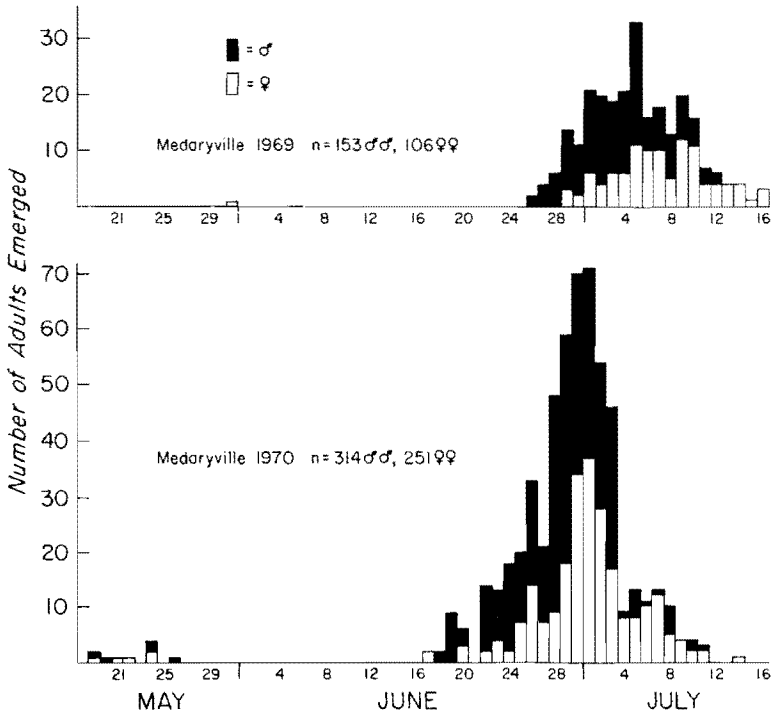

Fig. 1. The emergence at Urbana, Illinois, of adult promethea from overwintering cocoons that had been collected in the vicinity of Medaryville, Indiana, the preceding winter. The cocoons were held in a screened outdoor insectary at Urbana.

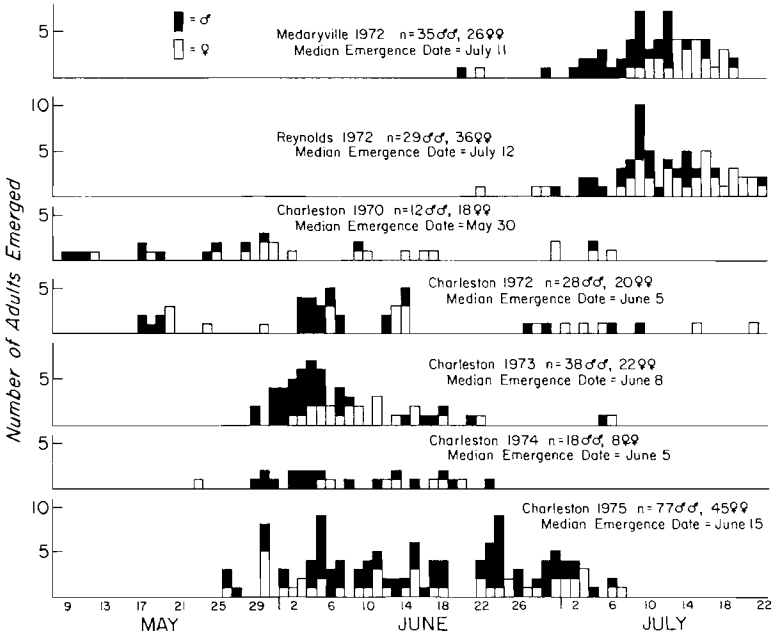

Fig. 2. The emergence at Urbana, Illinois, of adult promethea from overwintering cocoons that had been collected the preceding year in the vicinity of the indicated towns. The cocoons were held in a screened outdoor insectary at Urbana.

judged by progeny from its major emergence mode, was entirely univoltine with all of the F_1 progeny diapausing as pupae. We do not know if adults of the early Medaryville emergence mode produce non-diapausing progeny. Although the early mode is small, it is evolutionarily interesting.

In 1975 we reared the progeny of 21 pairs of wild-collected Charleston adults. The dates on which these pairs mated are indicated in Figure 3. Oviposition began on the evening of the day of mating. (Hereafter the progeny of one pair will be referred to as a sib group.) As shown in Figure 3, the proportion of the progeny that entered diapause increased as the season progressed. Eggs laid on or before 4 June yielded about 5% or fewer diapausing individuals. Eggs laid from 14 June to 22 June yielded up to about 20% diapausers. Eggs laid on or after 24 June yielded at least 80% diapausing individuals. Of the 21 sib groups included in Figure 3, 12 included both diapausers and non-diapausers, two included only diapausers, and six (two of 30 May, two of 1 June and two of 4 June) included only non-diapausers.

Table 2 presents data on the development of the non-diapausing individuals of all of the 1975 Charleston sib groups that included 40 or more non-diapausers. The mean development time from the beginning of oviposition to the emergence of the adult was 67.9 days for all larvae, but varied with sib group, ranging from 60 to 75 days. The development rate accelerated as the mean temperature increased with the advancing season. The fast development rate of sib groups J and K in the face of decreasing temperature is worth noting because it suggests that late hatching larvae may be able to compensate for low temperatures during development. However, the data are so meager that they do not warrant further analysis.

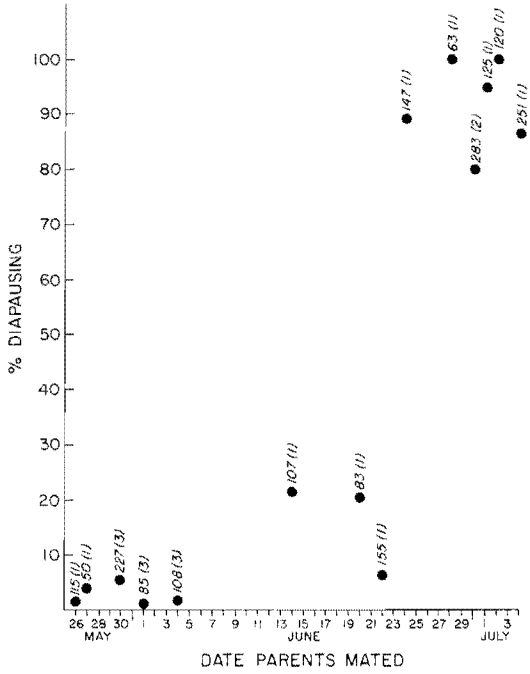

Fig. 3. The percent of diapausing pupae in 21 sib groups of promethea as it varied with the date on which the parents had mated. This is the day on which oviposition began. The parents emerged at Urbana from cocoons collected in the vicinity of Charleston in February of 1975. Above each dot are indicated the total number of pupae (both diapausing and non-diapausing) and in parentheses the number of sib groups.

Figure 4 shows the emergence dates of the adults that developed from the non-diapausing pupae included in Figure 3. The apparent but artifactual bimodality of the emergence results from the fact that we reared no larvae from eggs laid between 3 and 13 June. Emergence began on 2 August and continued until 8 September. We have no detailed data on the development or survival of the second generation produced by these adults. However, over the years we have found that the progeny of early emerging first generation adults survive to pupate while the progeny of adults that emerge in late August and September are not likely to survive. The latter grow slowly because of the usually low temperatures of September, and possibly because of declining food plant quality, and often do not manage to pupate before freezing weather occurs. In 1974 late larvae of the second generation were killed by an unusually early frost that ocurred on 2 October.

Sex ratios of the adults were skewed in favor of males (Figs. 1, 2, and 4) with the exception of the small 1970 Reynolds and Charleston samples. We have no explanation for this, but differential mortality during winter is not likely to be the reason because the Charleston F_1 progeny of 1975, which did not overwinter, also had a sex ratio strongly skewed in favor of males. Rau and Rau (1912) found a similarly skewed sex ratio at St. Louis, Missouri, with locally collected cocoons producing 116 males but only 67 females.

It is of some interest to compare promethea's seasonal history with that of the closely related cecropia moth, *Hyalophora cecropia* (L.), which is also abundant throughout most of the United States and southern Canada east of the Great Plains. Cecropia seems to be univoltine throughout its range. All cecropia populations thus far sampled have exhibited

Table 2. Origin, diapause and total development time of eleven sib groups[a] of the progeny of Charleston promethea. The adults were collected as pupae near Charleston in March of 1975. These progeny were reared at Urbana in the summer of 1975. Egg laying began on the evening of the day on which the parents mated.

		Non-diapausing Progeny				
Sib Group	Date Parents Mated	No.	%	Median Adult Emergence Date	No. Days Egg to Adult	Mean Temperature[b]
A	26/5	111	97.3	9/8	75	72.5
B	27/5	48	98.0	6/8	71	72.5
C	30/5	47	78.3	9/8	71	72.7
D	30/5	67	100.0	10/8	72	72.8
E	30/5	100	100.0	10/8	72	72.8
F	1/6	63	100.0	10/8	70	73.0
G	4/6	64	100.0	5/8	62	73.6
H	14/6	84	78.5	19/8	66	74.5
I	20/6	66	79.5	25/8	66	75.2
J	22/6	145	93.5	23/8	62	74.8
K	30/6	55	47.0	29/8	60	74.6

[a]Only sib groups with 40 or more non-diapausers are included. See Figure 3 for emergence data for other groups.
[b]Mean of daily mean temperatures from egg hatch to emergence.

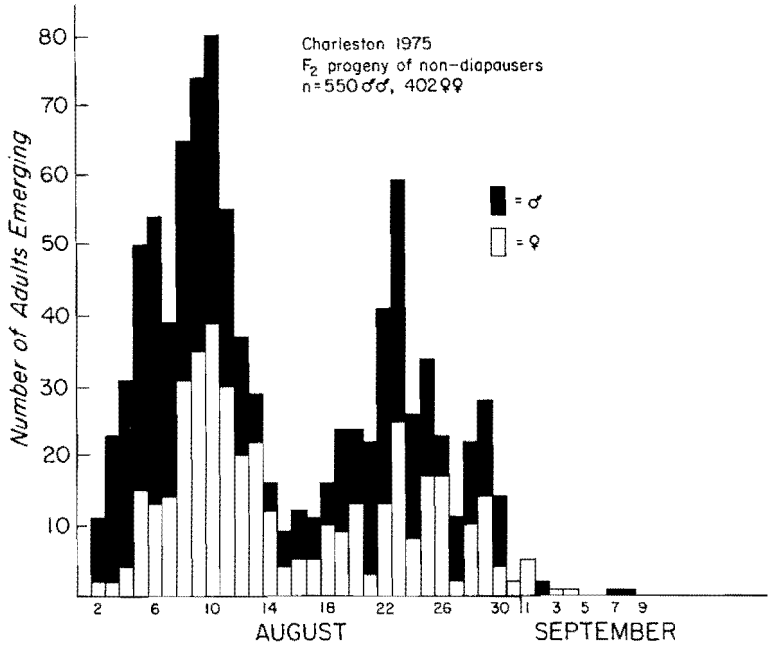

Fig. 4. The emergence of the adult progeny of some of the non-diapausing promethea that emerged at Urbana in 1975 from cocoons that had been collected in the vicinity of Charleston the previous winter.

a bimodal adult emergence pattern. At Urbana, Illinois, the early emerging group appears in late May and includes from 4.7% to 24.4% of the total emergence. The second emergence group appears in late June (Waldbauer and Sternburg 1973, Waldbauer 1978, Sternburg and Waldbauer 1978).

Promethea differs from cecropia most notably by being bivoltine in the southern part of its range. However, the seasonal history of the univoltine Medaryville population is very similar to that of cecropia, including a tendency to exhibit a bimodal emergence pattern.

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