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NATURAL HISTORY OF *GNOPHAELA LATIPENNIS* (BOISDUVAL) (ARCTIIDAE: PERICOPINAE) IN NORTHERN CALIFORNIA

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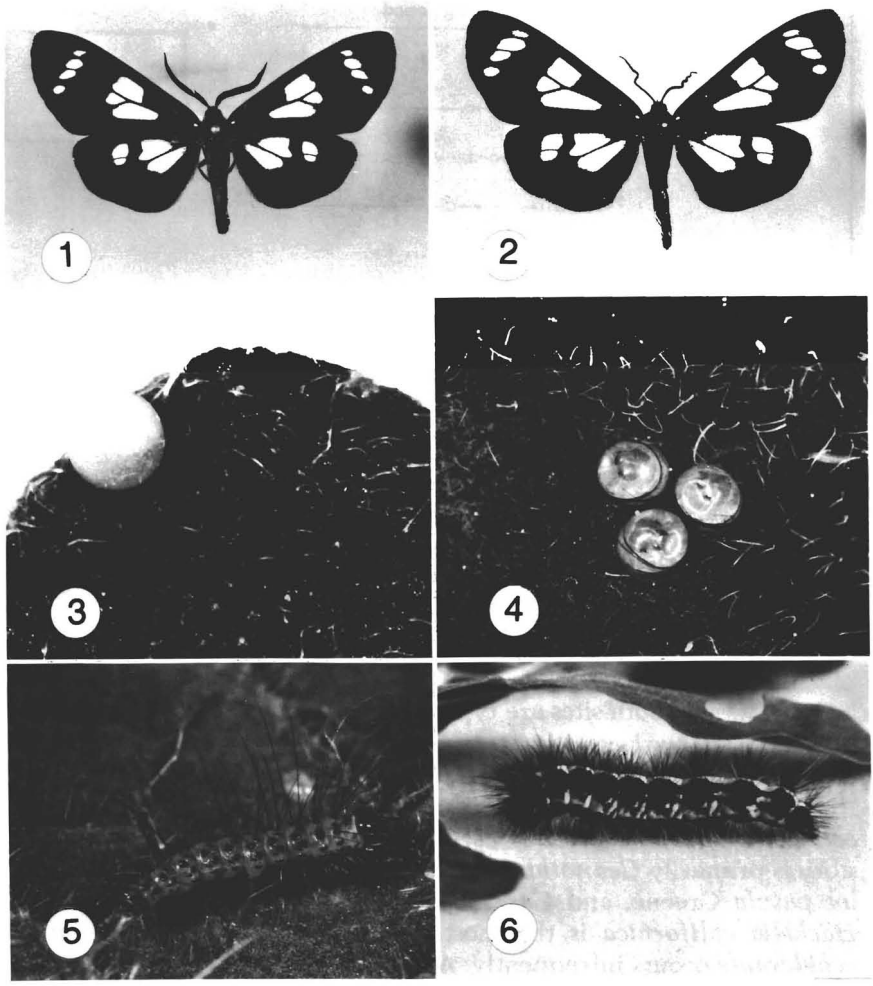
ABSTRACT. Diurnal *Gnophaela latipennis* (Boisduval) has a protracted summer flight and is univoltine with four larval instars, the second of which overwinters. Phenology and natural history of the egg, larva, pupa, and adult are discussed relative to the principal larval host, *Hackelia californica* (Gray) Johnston (Boraginaceae), in study areas in the northern Sierra Nevada. The egg, all larval instars, and pupa are described.

Gnophaela latipennis (Boisduval) (Arctiidae: Pericopinae) (Figs. 1, 2) is common to California, Oregon, and Washington, especially in the meadows and other forest openings of the Cascade, Sierra Nevada, and Coast ranges (Stretch 1872–1873, 1882, Dyar 1900, Powell & Hogue 1979, T. D. Eichlin, pers. comm.). Stretch (1872–1873, 1882) noted its abundance in the Siskiyou Mountains and Sierra Nevada. Its range extends from Easton, Kittitas Co., Washington [U.S. National Museum record (D. C. Ferguson, pers. comm.)] to "southern California" (the Illinois Natural History Survey has a specimen labeled "Santa Monica, S. Cal., 1 May 1879"), but its current distribution does not appear to extend south of Kern Co. (Greenhorn Mountains at the southern end of the Sierra Nevada) (J. P. Donahue, pers. comm.). It has been collected as low as 244–305 m [Big Creek Nature Reserve (University of California), Monterey Co., California] but more often at elevations ranging from 396–1890 m (J. A. Powell, pers. comm.).

Gnophaela latipennis occurs in localized populations (Stretch 1872–1873) as caterpillars (Figs. 5, 6) on boraginaceous hosts: *Cynoglossum grande* Douglas ex Lehmann, *C. occidentale* Gray, *Hackelia californica* (Gray) Johnston, *Mertensia* sp., and *Myosotis* sp. (Stretch 1872–1873, 1882, Dyar 1900, Donahue 1979, Powell & Hogue 1979) and as conspicuous black and white, diurnal moths (Figs. 1, 2) that fly lazily during nectaring and oviposition. The flight behavior is similar to that of *Gnophaela vermiculata* (Grote) in the Rocky (Cockerell 1889) and Uintah mountains.

Available literature on the natural history of *G. latipennis* is scant, and little is known about its phenology. The purpose of this paper is



FIGS. 1–6. *Gnophaela latipennis*. 1, adult male; 2, adult female; 3, undeveloped egg; 4, eggs ready to hatch; 5, first-instar larva; 6, last-instar larva.

to report on these matters relative to populations of *G. latipennis* in the northern reaches of the Sierra Nevada.

STUDY SITES AND METHODS

Field observations and collections focused on two areas during 1979–1983 in Plumas Co., California: Sunflower Flat, 1463 m, 4.8 km NWW of Chester; and Section 26 on Mud Creek Rim, 1676 m, 6.4 air km

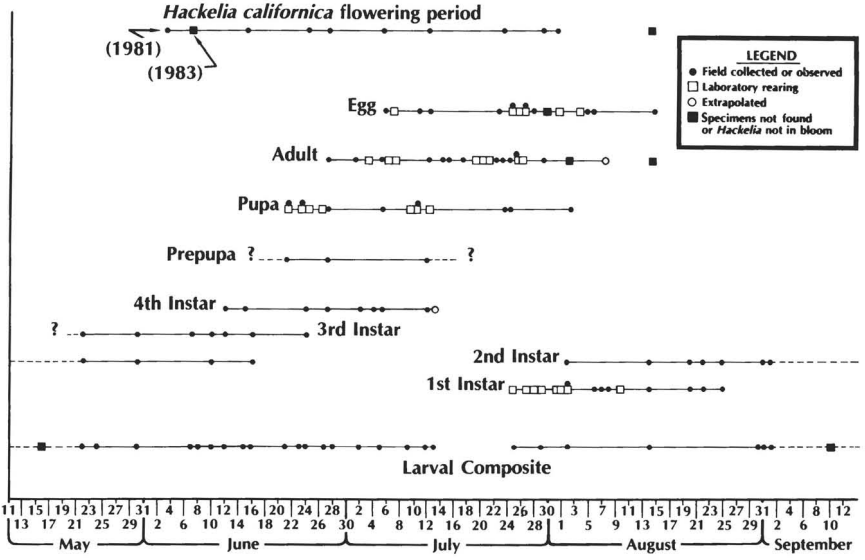


FIG. 7. Phenology of *Gnophaela latipennis* in relation to the flowering period of its principal host, *Hackelia californica*, near Chester, Plumas Co., California.

NE of Chester. Both sites are typical Sierran montane forests disturbed by earlier timber harvesting activity. The dominantly coniferous vegetation is a mixture of *Abies concolor* (Gordon & Glendinning) Lindley, *Pinus lambertiana* Douglas, *P. jeffreyi* Greville & Balfour, and *Libocedrus* (*Calocedrus*) *decurrens* (Torrey) Florin. The shrubby understory is primarily *Ceanothus velutinus* Douglas ex Hook, *Arctostaphylos patula* Greene, and *Castanopsis sempervirens* (Kellogg) Dudley. *Hackelia californica* is the most abundant herb, and *Cynoglossum occidentale* occurs infrequently. Additional observations were made in Butte Co., 11.2 air km SE (Brown's Ravine, 1585 m) and 14.5 air km SE (1890 m) of Butte Meadows. These areas are 40 air km SW of Chester.

Site examinations and observations began with receding snow cover in mid-May and continued with occasional unavoidable interruptions into September. Field data were composited into a generalized seasonal history (Fig. 7). Part of the generalization was extrapolated by determining the durations of the egg and pupal stages under ambient laboratory temperature, and by noting the hatching of field-collected eggs to establish the onset of the first larval instar.

Hinton's (1946) setal nomenclature was used in the larval descriptions.

OBSERVATIONS AND DISCUSSION

Adult. The adults (Figs. 1, 2) of *Gnophaela latipennis*, a univoltine species, exhibited a protracted summer flight period (Fig. 7). They emerged from field pupae by 27 June and were numerous and active during the first three weeks in July; but adults observed after that time appeared weak and ragged. The last field sighting of an adult during the 4-year period was 29 July. However, egg clusters were seen on three later occasions, one as late as 14 August. As the minimum hatch-time of a *G. latipennis* egg is about seven days (discussed under "Egg"), the female that laid the eggs would have been alive at least through 7 August. Thus, observed and extrapolated information indicates that adults fly between 27 June and 7 August in the Sierra Nevada study areas. In the Coast Range of California, adults have been observed as early as 25 May (8.0 air km SE Hayfork, Trinity Co.), 5 June (UC Big Creek Nature Reserve, 244–305 m, Monterey Co.), 8 June (emergence) (Buttercreek Meadows, 12.9 km W Hayfork, 1143 m, Trinity Co.), and 9 June (Kelseyville, Lake Co.) (Powell, pers. comm.).

Hackelia californica, the principal larval host at the study sites near Chester, was used extensively by adult *Gnophaela latipennis* for nectar. Its flowering period began approximately three weeks before the first *G. latipennis* adults emerged (heavy snow cover during the winter of 1982–1983 resulted in a late spring, hence the lack of blossoms on 7 June 1983) and overlapped their flight period through 31 July (Fig. 7). By the third week of July, however, most blossoms had been succeeded by well-developed nutlets. These nutlets are covered with prickles (Munz 1970), and two adults were found stuck to them on 29 July and five on 23 July 1980. *Gnophaela latipennis* also nectared at the flowers of *Cynoglossum grande* (Butte Co.), *C. occidentale*, and *Helianthus* sp. The latter, plus *Senecio*, were visited by *Gnophaela vermiculata* in the Rocky Mountains (Cockerell 1889).

Many pairs of *G. latipennis* were observed mating between 5–25 July on nectar plants, larval host plants, adjacent vegetation, and once on the end of a *Pinus jeffreyi* branch. One mating pair remained coupled for 3 h; a second pair, for 10 h.

Egg. Eggs occurred from 5–14 July (Fig. 7) and were usually found in clusters on the undersides of larval host plant leaves, as observed on *Hackelia californica* and *Cynoglossum occidentale*. However, eggs also were sporadically found on such unrelated plants as *Pinus jeffreyi* (Pinaceae) (22 eggs among needles), *Stipa* sp. (Gramineae), and *Ceanothus velutinus* (Rhamnaceae) (10 eggs on the underside of a leaf).

The number of eggs per cluster laid in the laboratory ranged from 5–13 ($\bar{x}$ = 10.3/cluster, SD = 2.6, n = 7), whereas field-collected eggs

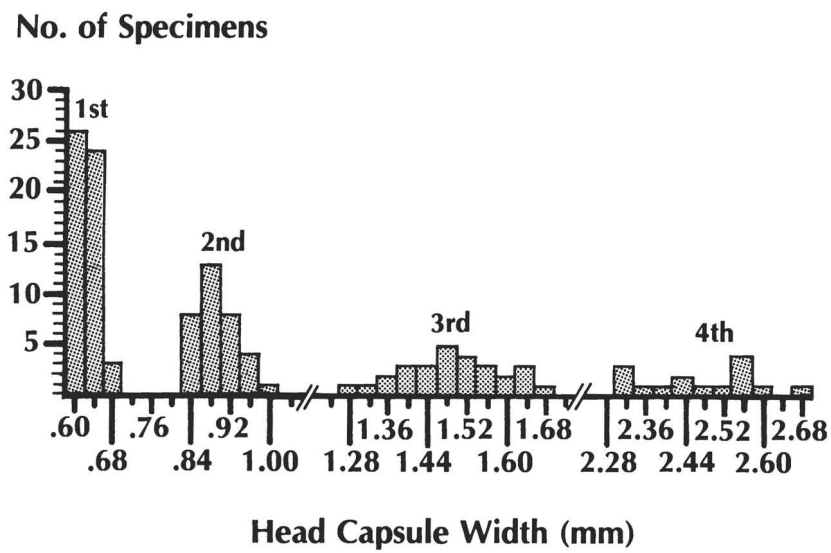


FIG. 8. Measurements, frequency, and distribution of *Gnophaela latipennis* head capsule widths based on field-collected and reared larvae.

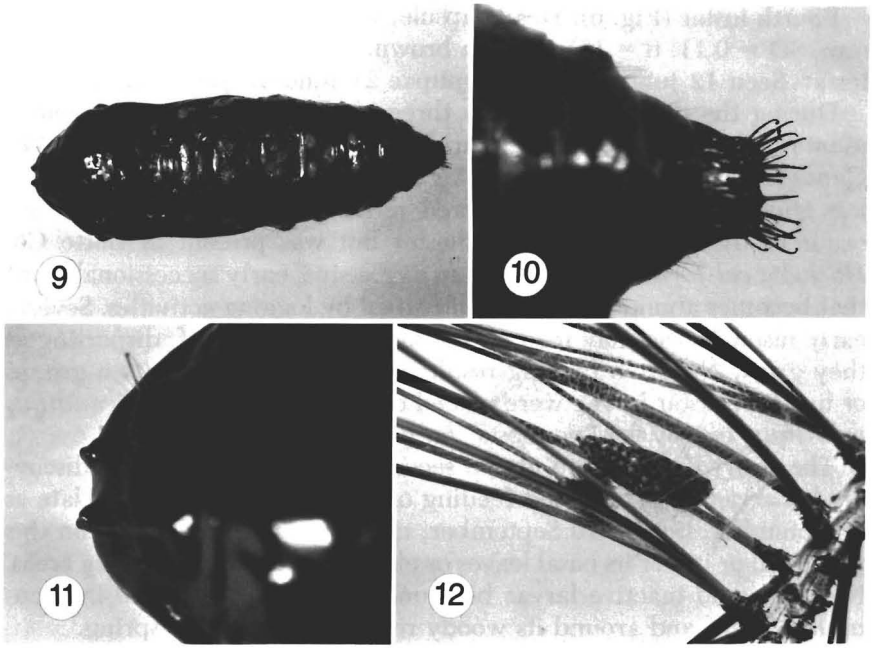
from larval host plants ranged from 1–21 ($\bar{x}$ = 10.0, SD = 6.5, n = 14). The egg clusters from *Pinus jeffreyi, Stipa* sp., and *Ceanothus velutinus* were disregarded in determining cluster size. The total egg complement of *Gnophaela latipennis* females was not fully determined, but a single female field-collected *in copula* on 5 July laid 157 eggs the following day, and a second female that emerged and mated in the laboratory produced 109 eggs.

The newly laid egg (Fig. 3) is smooth, spherical, yellow, and measured 1.25–1.32 mm in diameter ($\bar{x}$ = 1.31 mm, SD = 0.03, n = 6). Shortly before hatching, the head capsule and long, black, body setae were easily visible through the chorion (Fig. 4). The top of the egg collapsed near the head capsule. During hatching, the mandibles may be seen, under magnification, biting at the collapsed region to effect an exit hole for the larva.

Hatching time was 7–8 days; in one laboratory situation, 19 of 34 eggs hatched in seven days (15 failed to hatch) and in a second case, 37 of 38 eggs hatched between seven and eight days (1 failed). The maximum stage duration of any field-collected eggs was seven days (2 collected on 22 July 1983 hatched on 29 July).

Larva. Four larval instars were determined by the distribution and frequency of head capsule widths of field-collected and reared larvae (Fig. 8):

First instar (Fig. 5). Head capsule, width 0.60–0.68 mm ($\bar{x}$ = 0.62



FIGS. 9–12. *Gnophaela latipennis* pupa. 9, habitus (dorsal); 10, cremaster (dorsal); 11, head tubercles (dorsal); 12, in cocoon on *Pinus jeffreyi* (head towards branch).

mm, SD = 0.02, n = 52), tan, setae translucent. Body translucent greenish yellow with distinct black tubercles on T-2–Ab-9; cervical shield yellowish tan, setae translucent, majority of D and SD setae longer than body diameter and black; L and V setae shorter and translucent; D and SD on Ab-1–Ab-8 unisetose; crochets in homoideous mesoseries. Active 25 July–25 August (Fig. 7).

Second instar. Head capsule, width 0.84–1.00 mm ($\bar{x}$ = 0.89 mm, SD = 0.04, n = 34), reddish brown, setae tan to black. Body initially concolorous with first instar but cervical shield darkens, black stripes appear, SD and D1 tubercles become slightly iridescent bluish black; D and SD setae subequal in length to body diameter, most tubercles multisetose; crochets heteroideous mesoseries. Extends from 2 August–16 June (overwinters) (Fig. 7).

Third instar. Head capsule, width 1.28–1.68 mm ($\bar{x}$ = 1.49 mm, SD = 0.10, n = 28), concolorous with preceding instar. Body yellow and black striped, tubercles iridescent blue; D and SD setae shorter than body diameter; otherwise similar to second instar. Seen from 22 May–24 June (Fig. 7). (The occurrence on 22 May indicates that some third instars may overwinter.)

Fourth instar (Fig. 6). Head capsule, width 2.32–2.68 mm ($\bar{x}$ = 2.47 mm, SD = 0.11, n = 15), reddish brown. Body concolorous with third instar. Seen 12 June–13 July; prepupae 21 June–12 July (Fig. 7).

During the study period, only three of the five borages previously mentioned had *G. latipennis* larvae on them: *Hackelia californica*, *Cynoglossum occidentale*, and *C. grande*. The latter two species were less abundant and were considered minor hosts; *C. grande* did not occur in the study sites near Chester but was present in Butte Co. *Hackelia californica* seems to be an aggressive, early successional plant that becomes abundant in areas disturbed by logging activities. Several early instar larvae may feed on the same host-plant leaf, dispersing as they grow. Negative feeding results were obtained when two groups of five first-instar larvae were placed on *Pinus jeffreyi* and *Ceanothus velutinus*, two of the "nonhosts" on which eggs were found.

The overwintering site of the second-instar larvae was not discovered. Larvae were observed feeding on *Hackelia californica* as late as 1 September, but by 10 September, no larvae could be found on this perennial or under its basal leaves or elsewhere in known feeding areas. Neither could inactive larvae be found under *H. californica* in accumulated duff and around its woody root crowns in early spring.

In 1982, spring larvae were detected feeding at Sunflower Flat on 22 May; none had been seen there six days earlier. At Section 26, no larvae were found on 16 May when *H. californica* was 2.5 cm tall and snow patches still persisted, but by 30 May, larvae were seen feeding on this host plant when it was 7.6 cm tall. Of the three larvae collected on 22 May, two were third instars, which indicates that they also may overwinter; however, none were seen in the fall.

The latest date that last-instar larvae were observed actively feeding (13 July) is one day later than the latest date for prepupae (12 July). The earliest date a prepupa was seen (21 June) coincides with the first pupal record (Fig. 7). Therefore, the prepupal time line in Fig. 7 should be extended in both directions, but there are insufficient data to determine extention lengths.

Pupa. Pupae occurred from 27 June–2 August (Fig. 7), and the duration of single pupae was 9–12 days ($\bar{x}$ = 10.5 days, n = 11) based on the pupation dates of field-collected, last-instar larvae, and the adult emergence dates.

The pupa is black with conspicuous yellow to orange abdominal spots (Fig. 9), is slightly "hairy," and ". . . suspended hammocklike . . ." (Powell & Hogue 1979) by its cremaster (Fig. 10) and two head tubercles (Fig. 11) inside a white, loose, lacelike cocoon (Fig. 12). Only two of the dozens of pupae (and three prepupae) found during this study were in *Abies concolor* foliage. Most were seen in young *Pinus*

jeffreyi at heights ranging from 1.8–3.7 m, where the cocoons had been spun solitarily among the needles. Much time was spent searching unsuccessfully for pupae in other tree and shrub species, but the absence of pupae on other vegetation or on the ground does not preclude the possibility of undetected predation. For *Gnophaela vermiculata*, Bruce (1888) noted "... when full grown the whole brood [larvae] appears to make for the nearest detached rock where they spin their cocoons in angles and crevices, generally in clusters, and often covering each others [Sic] cocoons so thickly that many of the moths are not able to make their way through but die crippled." Although one *G. latipennis* moth was seen in the field with deformed wings, obviously unable to escape from the cocoon, no general deformity problem was evident.

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