NOTES ON THE DIAPAUSE OF LEPIDOPTERA IN HOT ARID SUBTROPICAL CLIMATES

by E. P. WILTSHIRE

All univoltine (single-brooded), most bivoltine (double-brooded), and many multivoltine (more than two broods per year) Lepidoptera species in hot arid subtropical climates such as the Middle East perform a summer diapause (æstivation), as well as a winter diapause (hibernation) in localities with a cold winter. Most of these species do so as pupæ.

Two early articles of mine (Wiltshire, 1938, 1941a) gave details of the phenology of this diapause in univoltine species. In some bivoltine species, the two broods are vernal and autumnal, æstivation separating them; in others, the two generations are consecutive and the diapause combines æstivation and hibernation and appears in alternate generations. In some multivoltine species the first two broods are consecutive and are separated by æstivation from later, autumnal generations, of which there is sometimes only one.

These however are generalisations based on the noted season of flight of the wild adults. The example, well-known in Europe, of the univoltine genera *Xylena* and *Lithophane,* with adults appearing twice a year (in autumn and again in spring after hibernation and sexual maturation), is a warning against judging entirely from the noted season of flight. For twenty years therefore, in the Middle East, I have kept notes of the dates of breeding various species, in case these might correct wrong judgments about phenologies. The following results in two congeneric bivoltine species, bred *ex ovo,* though not revealing anything so deceptive as the appearance of *Xylena,* etc., are nevertheless of interest.

Caradrina zobeidah Boursin appears to be bivoltine, as the adult only comes to light in March-April and October in Bagdad. *Caradrina bodenheimeri* Draudt seems also to be bivoltine, as the adult is only taken wild in spring and again in autumn; it is widespread in hilly places in S.W. Asia, but the breeding was from a Shiraz (S.W. Iran) female.

Breeding these two species from ova laid by gen.I females produced a split emergence of gen.II, part in June and part in October. Both were bred indoors, at a lower temperature than that prevailing out of doors, and this may account for the earlier appearance of part of the second generation. In captivity therefore these bivoltine species appeared three times annually, but since no matings were obtained from the June adults it was impossible to say whether they were in fact partially trivoltine, *i.e.* with three annual generations. In both species the first generation consisted of larger specimens than the succeeding broods.

Similar behaviour has been noted in the Hadenid genera *Discestra* and *Cardepia* in the arid Middle East: ANDRES (1924, p.35) stated he had bred *Discestra trifolii* Rott. from April pupæ from larvæ found in the Fayoum, Egypt, imagines hatching in May and October; and breeding *Cardepia albipicta* Christ. at Ahwaz (S.W. Iran), where it is bivoltine in a wild state, flying

in April and October, I found that in captivity the second generation emerged partially in May. Only in *Caradrina, Cardepia,* and *Discestra* do I know of this sort of occurrence, though I have bred many families for many years. There are, however, probably other groups in which it occurs. This phenology may be generic, just as contrasting phenologies characterise related groups.

The above results, excluding those of ANDRES, were *ex ovo* and the behaviour is that of offspring of single mothers. In the following cases, however, a similar phenology was observed in pupæ from larvæ that were collected wild; they were contemporary but not necessarily of a single parent.

Notodonta ziczac L. does not reach such hot arid localities as the foregoing but in N. Iran at 6000 ft. it inhabits a biotope with a long dry summer and performs both æstivation and hibernation. Breeding from it I observed a split similar to those mentioned above, occurring in gen.I pupæ though later in the year. At Derband near Tehran four young larvæ were found that had evidently hatched about 5 June; they pupated 27-30 June. Three adult moths hatched in late August, and one in April next year. The longer diapause of the later individual combined æstivation with hibernation, while even the shorter pupal period of the other three comprised a distinct æstivation of nearly two months. Breeders in temperate climes will be able to give many parallel instances of this "partial second brood."

Papilio machaon L. is a multivoltine species that appears five times annually and probably has three or four annual generations at Bagdad and Shiraz. The third generation adults here may appear, promptly without diapause, in June and July, or after a pupal diapause in September and October. This butterfly's phenology is however very complicated, and fuller details of its biology at Bagdad will be published separately. The phenological split in the third generation seems to be a parallel to that in the second generation of the bivoltine cases described above.

To conclude: in hot arid subtropical climates, in most species it is not possible to break the diapause by breeding experiments; still less is it broken in the wild state. But in a few species, not univoltine, a premature partial hatch of adults occurs in bred pupæ in midsummer of which there is usually no sign in the wild state. If we exclude multivoltine species such as *machaon,* the word "usually" can be omitted in the foregoing sentence. It is nevertheless possible that even in a wild state a few individuals may hatch prematurely in midsummer, though this has not been observed.

This phenological plasticity may well enable the species to adapt itself to climatic change: it would enable a species to spread to a region with a slightly different climate, or to survive on the spot if geological time brought climatic change.

In another article (Wiltshire, 1941b) I mentioned the peculiar two-broodedness of *bodenheimeri* and *arenaria* Hamps. (recte *albipicta*) and suggested it might have evolved comparatively recently from a multivoltine phenology, as an adaptation to aridity and heat. I still think this is probably the truth, and that a univoltine phenology is a further sep of irrevocable specialisation, in the same direction, due to similar environment.

One frequently reads suggestions that winter cold has caused the evolution of the diapause; writers in temperate climes are apt to forget the equally important role of arid heat.

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Airmail address: E. P. Wiltshire (Personal), British Embassy, Bagdad, IRAQ

THE LARVA OF *HYPERÆSCHRA GEORGICA* (NOTODONTIDÆ)

by ALEXANDER B. KLOTS

Thrice during the last two years I have found at Putnam, Connecticut, on *Quercus* larvæ of a Notodontid which corresponded to nothing recorded in the literature. A larva found in August, 1955 pupated but died during the winter; another found in July, 1956 was parasitized; but the third, also found in July, 1956, transformed the same year to the adult. This proved to be *Hyperæschra georgica* (Herrich-Schaeffer). These larvæ were nothing like the description of the larva of *georgica* given by FORBES (1948, p.220). FORBES, however, took his information from PACKARD (1895, p. 153), the only available source; and PACKARD merely quoted a MS of RILEY'S based on southern larvæ. The following description therefore corrects a mixup of long standing. It is doubly important to do so since it will bear importantly on the question whether *georgica* really belongs in *Hyperæschra.*

Length of mature larva 45 mm. Color very light gray green, almost whitish dorsally, deepening and darkening to olive green just above the immediately subspiracular lateral line, below that olive green. Lateral line yellow, slightly brighter on head; on body fading dorsally to whitish, finely edged both ventrally and dorsally with dark, the ventral edging reddish and the dorsal edging blackish; continuous from outer edge of mandible and antenna, below stemmata, almost to posterior (median) end of anal plate where it fades out.

Head light gray-blue-green, reticulated with darker and lighter shades of the same hue; edges of epicranial suture lighter; stemmata black. Thoracic segments lighter than those of abdomen. Body with a pair of narrow, indistinct, whitish subdorsal lines very close together. Laterad of these, on each segment, 3 small whitish warts, longitudinally arranged; laterad of these an irregular, longitudinal line of 8-11 small whitish dots; laterad of these a similar, irregular longitudinal line of 7-9 small whitish dots; laterad of these the line of the spiracles and the longitudinal line. Spiracles oval, whitish, narrowly