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OBSERVATIONS ON THE BIOLOGY OF *DELIAS HARPALYCE* (DONOVAN) (LEPIDOPTERA: PIERIDAE) NEAR MELBOURNE, VICTORIA

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Abstract

Observations on the life cycle and general biology of the large pierid butterfly, *Delias harpalyce*, were made between 1985 and 1990 near Melbourne, Victoria. Three mistletoes *Amyema miquelii*, *A. pendulum* and *Muellerina eucalyptoides* were utilised in approximately equal frequency. Populations were bivoltine with early-spring and mid-summer generations. Adults occurred in each month but were scarce between May and August. Adults of winter cohorts emerged over 4-9 days and in a 1:1 sex ratio. Pupal polyphenism is described and the two colour forms are shown to be seasonal: orange pupae predominate in summer and black pupae in winter. In summer generations larvae pupated solitarily or in small groups, pupal webs were substantially smaller and the pupal stage varied from 3-4 weeks, compared with 6-10 weeks in winter. It is hypothesized that the black pupal morph plays an important adaptive role in thermoregulation and development during harsh winter conditions of low temperatures.

Introduction

The common imperial white butterfly, *Delias harpalyce* (Lepidoptera: Pieridae), is confined to south-eastern Australia and is the only member of the genus with a strictly temperate distribution (Common and Waterhouse 1981). Descriptions and habits of the early stages were first reported by Anderson and Spry (1893) and Rainbow (1907); further details were given by Waterhouse (1932), Barrett and Burns (1951) and McCubbin (1971). The species is reported to have two generations annually (Common and Waterhouse (1972, 1981), and near Melbourne adults fly from late August to early May (Braby 1987). Larvae specialise on at least two mistletoe species (Loranthaceae), *Muellerina eucalyptoides* (DC.) B.A. Barlow and *Amyema miquelii* (Lehm. ex Miq.) Van Tiegh. (Common and Waterhouse 1981). Compared with most other members in the genus which have orange or yellow pupae, *D. harpalyce* is distinctive by its pupae being shiny black. However, an orange pupal form was reported recently (Coupar 1988, Braby and Berg 1989, Douglas and Braby 1989) and the presence of this phenotype prompted us to investigate the life cycle and general biology in more detail. In this paper we examine the host plant spectrum, larval and pupal habits, extent of pupal polyphenism, seasonality and adult temporal distribution.

Methods

Observations on the early stages and general biology of *D. harpalyce* were made intermittently between 1985 and 1990, predominantly in the north-eastern suburbs of Melbourne, but also in central Victoria and the coastal areas south-east of Melbourne. Information on larval hosts, pupal habits

and colour, seasonality, flight period and adult emergence was collected. Overall, 53 records of the early stages on host plants were obtained. For studies on adult emergence, six different cohorts (i.e. a group of larvae or pupae derived from the same egg batch), five of which comprised pupae and the other as final instar larvae, were collected in August 1988. They were placed in a rearing cage (2 x 1 x 1 m) at Eltham and the numbers of males and females which emerged were recorded.

Results

Host plants

The early stages of *D. harpalyce* were recorded on *A. miquelii*, *A. pendulum* (Sieber ex Spreng.) Van Tiegh. and *Muellerina eucalyptoides* parasitising eucalypts and acacias (Table 1). Of the 15 tree species, only *Eucalyptus polyanthemos* Schauer and *E. radiata* Sieber ex DC. supported all 3 host plants. The distribution of *D. harpalyce* across the mistletoes was approximately equal: *A. miquelii* (n=19, 36%), *A. pendulum* (n=21, 40%), *M. eucalyptoides* (n=13, 24%); the slight differences observed in host frequencies were not significant ($p > 0.25$).

Immature stages

Similar to descriptions given by Common and Waterhouse (1981) except pupae were also light orange or dark reddish, usually with black thoracic ridge and black abdominal spines and spiracles (Fig. 1). Some orange

Table 1. Mistletoes utilised by *D. harpalyce* and their host trees.

Host tree	Mistletoe		
	<i>Muellerina eucalyptoides</i>	<i>Amyema pendulum</i>	<i>Amyema miquelii</i>
<i>Eucalyptus camaldulensis</i>	+		
<i>E. ovata</i>		+	
<i>E. pryoriana</i>		+	
<i>E. cephalocarpa</i>		+	
<i>E. obliqua</i>	+	+	
<i>E. macrorhyncha</i>	+	+	
<i>E. radiata</i>	+	+	+
<i>E. polyanthemos</i>	+	+	+
<i>E. gonitocalyx</i>	+		+
<i>E. melliodora</i>			+
<i>E. microcarpa</i>			+
<i>E. behriana</i>			+
<i>Acacia mearnsii</i>			+
<i>A. melanoxydon</i>	+		
<i>A. penninervis</i>	+		



Fig. 2. Black pupal phenotype of *D. harpalyce* and pupal web on *Amyema miquelii*, Steels Creek, August 1988.



Fig. 1. Orange pupal phenotype of *D. harpalyce* on *Amyema pendulum*, Mitcham, January 1987.

pupae contained considerable amounts of black on the thorax and wings. Black pupae were occasionally noted with varying amounts of red on the thorax and abdomen (Fig. 2). Pupal stage varied from 3-4 weeks in summer to 6-10 weeks in winter.

Pupal polyphenism and seasonality

Final instar larvae constructed silken webs to which they attached themselves by the cremaster and a central girdle (Figs. 1 & 2). The webs were suspended amongst the host foliage, and the number of pupae, pupal exuviae or late instar larvae per cohort varied considerably (Fig. 3), although most cohorts (75%) were of less than 30. One very large web which comprised 93 pupae may have been derived from progeny of two cohorts. A frequency distribution of the seasonal occurrence of pupal cohorts (Fig. 4) revealed two distinct peaks which corresponded to two generations, one in August and another in December. Winter pupae were predominantly black, the webs large and well developed (Fig. 2), and were usually exposed on the northern or north-western side of the mistletoe clump facing the sun. In contrast, pupae in summer were generally bright orange, the webs were considerably smaller with pupae solitary or in small groups (Fig. 1), and were often in a shaded part of the clump.

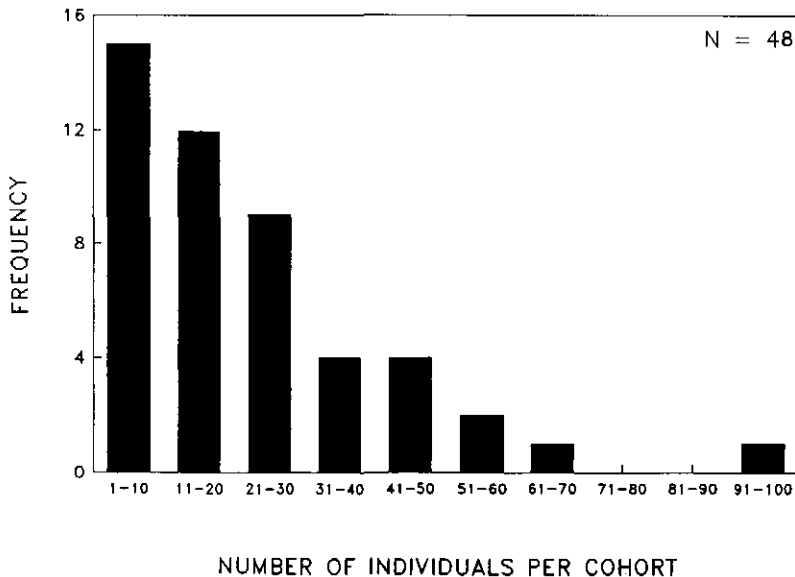


Fig. 3. Frequency distribution of the number of pupae, pupal exuviae or late instar larvae of *D. harpalyce* recorded for cohorts, 1985-1990.

Seasonal variation in adult form between these two generations was evident, and conformed to the general descriptions given by Couchman (1954). In particular, spring bred specimens of both sexes had a restriction in the scarlet postmedian band on the hindwing underside; in summer specimens the scarlet markings were considerably broader.

Flight period and adult emergence

Adults were observed in each month but were most numerous between September and April; the few records obtained for May-August are listed in Table 2. Adults were also noted by Waterhouse and Lyell (1914), McCubbin (1971) and Burns and Rotherham (1969) in August. Adult emergence, for the six cohorts collected in August 1988, occurred over a relatively short period of 4-9 days with the sexes emerging at approximately the same time (Fig. 5). The sex ratio of these adults, although slightly male biased (1.14, 83♂/73♀), was not significantly different from 1:1 ($p > 0.25$). Adults were observed to expand their wings within 30 min of emergence but were not able to fly for 1-2 days; apparently taking this length of time before their wings were fully hardened.

Table 2. Late autumn and winter records of adult *D. harpalyce* near Melbourne, 1985-1990.

Locality	Date	Comments	Source
Warrandyte	4.v.1985	1♂ fresh	pers. obs.
Christmas Hills	9.v.1987	2♂ sl.worn	M.F. Braby (1987)
Mt Riddell, Healesville	9.v.1989	1♀ fresh	pers. obs.
Mt Riddell, Healesville	14.v.1989	1♂ fresh	pers. obs.
Frankston	4.vi.1988	♂ & ♀	obs. J.L. Ross (pers.comm.)
Greens Bush, Mornington Peninsula	30.vi.1990	emerged	M.&P. Coupar (pers.comm.)
Dromana, Mornington Peninsula	vi.1990	emerged	D. Holmes (pers.comm.)
Dromana, Mornington Peninsula	vii.1990	1♂ obs.	D. Holmes (1990)
Kinglake	vii.1990	1♂ obs.	J. Burns (pers.comm.)
Mt Riddell, Healesville	25.vii.1990	1♀ fresh	pers. obs.
Blairstown, Mornington Peninsula	17.viii.1986	emerged	M. Le Souef (1986)
Steels Creek	26.viii.1987	1♀ fresh	M.F. Braby (1987)

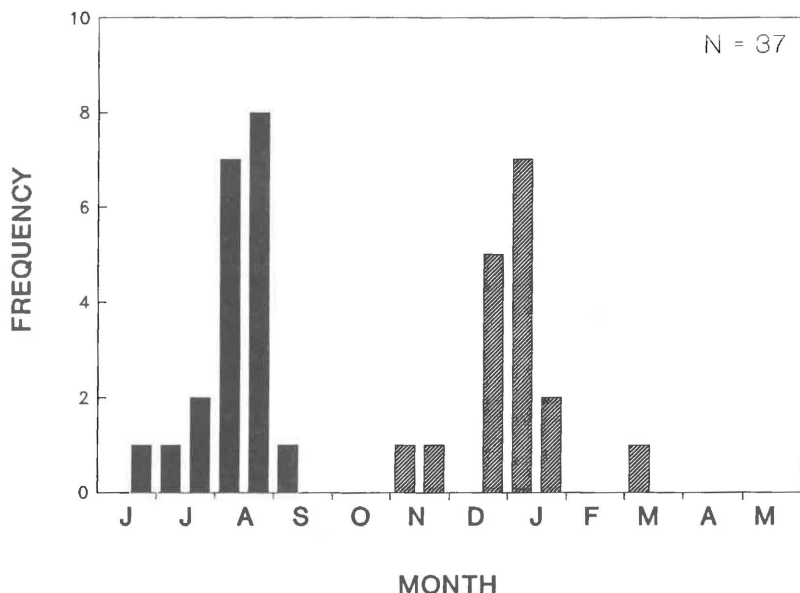


Fig. 4. Seasonal distribution of *D. harpalyce* pupal cohorts, 1985-1990. Records are grouped into half months. Closed bar = black pupae, hatched bar = orange pupae.

Discussion

Host plants

D. harpalyce is now recorded utilising three mistletoe host plants. Although *A. pendulum* was not listed by Common and Waterhouse (1981), it had been noted by earlier authors (Anderson and Spry 1893, Barrett and Burns 1951, Burns and Rotherham 1969, McCubbin 1971). The host was frequently used in many areas around Melbourne, and these records confirm earlier observations. There is also an unconfirmed record of the butterfly utilising *A. quandang* (Lindl.) Van Tiegh. (Condron 1974), and some late instar larvae collected by K.L. Dunn (pers. comm. 1984) from *Muellerina* near Newcastle, New South Wales, were successfully reared on *Dendrophthoe vitellina* (F. Muell.) Van Tiegh. As the larvae were close to pupation the extent to which *D. harpalyce* uses *Dendrophthoe* is not known.

Seasonality

D. harpalyce is clearly bivoltine but the second (summer) generation

occurs much earlier than previously reported (Barrett and Burns 1951, Burns and Rotherham 1969, McCubbin 1971). Following emergence of adults in September-October, second generation adults appear approximately 3-4 months later in December-January rather than in "February-March". Anderson and Spry (1893) originally stated that "...the greater number of eggs or larvae appear either in July or August, or February and March." Subsequent authors appear to have confused this seasonal pattern of eggs and larvae with pupae and adults.

The seasonal history during autumn and early winter perhaps deserves further study however. Eggs and early instar larvae were numerous in late March-early April, but only one pupal cohort was recorded in March. Presence of these pupae in autumn, as well as freshly emerged adults in May-August, may represent advanced cohorts which managed to pupate before winter. Alternatively, it is possible that in some areas or seasons, a third 'autumn' generation may occur. For example, larvae reared in captivity by K.L. Dunn (pers. comm. 1985) from eggs collected in December from Barrington Tops, N.S.W., and from eggs in February from Murrindal, eastern Victoria, produced adults in February and April-May, respectively.

Larval and pupal habits

D. harpalyce larvae feed gregariously, spin considerable amounts of silk over the host foliage and branches, and usually moult and pupate together. In both broods, pupae were orientated upwards (the illustrations in Morrison 1939 and Barrett and Burns 1951 are depicted upside down) and there was no evidence of webs being constructed early in larval life (i.e. second instar) as suggested by earlier authors (Anderson and Spry 1893, Rainbow 1907, Common and Waterhouse 1972, 1981). Only in the first (winter) generation did final instar larvae construct a large web and pupate gregariously. Second (summer) generation larvae pupated singly or in small groups, a habit more commonly seen in other closely related species, for example, *D. mysis* (F.) (Barrett and Burns 1951, McCubbin 1971), *D. argenthona* (F.) (pers. obs.), *D. nigrina* (F.) (Common and Waterhouse 1981, Nousala 1979) and usually *D. aganippe* (Don.) (Common and Waterhouse 1981, pers. obs.). The pupal web in *D. harpalyce* may serve the dual function of providing structural support and, in the winter brood, maximising the incidence of sunshine to enhance pupal development.

D. harpalyce larvae on one occasion were observed to leave the host plant when the host foliage had been stripped, and pupate on grass or shrubs by lowering themselves to the ground on a thread of silk, a behavioural trait more often exhibited by *D. nigrina* and *D. argenthona* (pers. obs.) and *D. ennia nigidius* Miskin (Quick 1982a,b). On another occasion 47 larvae of *D. harpalyce* were found in sympatry with 14 *D. aganippe* larvae on *A.*

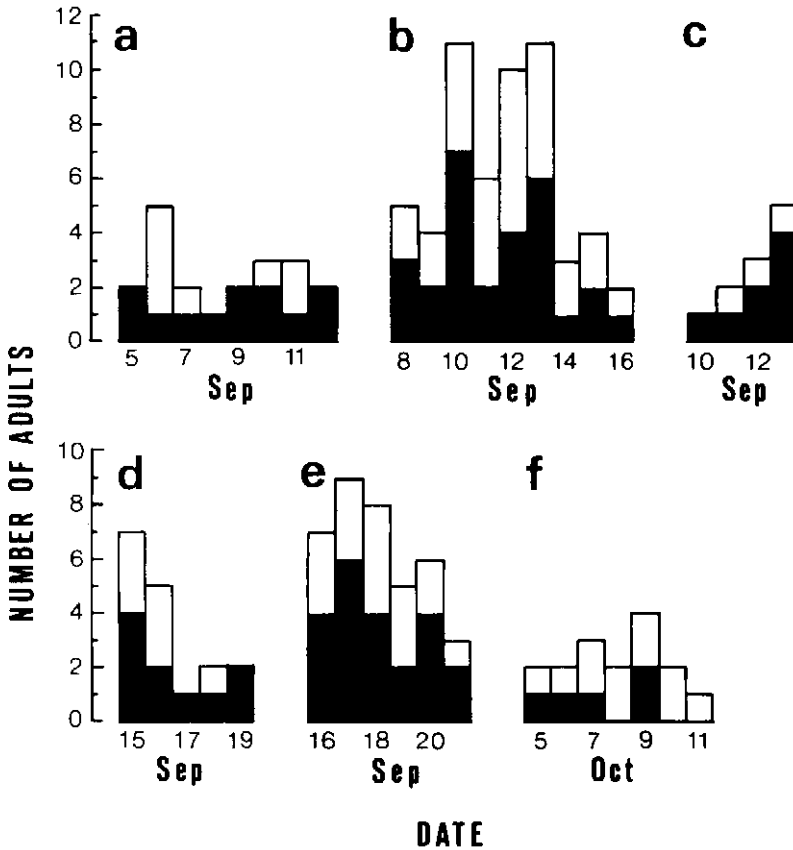


Fig. 5. Number of adults emerged for *D. harpalyce* cohorts collected in August 1988 (a) Panton Hill, (b) Steels Creek I, (c) Mangalore, (d) Benalla, (e) Steels Creek II, (f) Steels Creek III. Closed bar = males, open bar = females.

miquelii at Eltham; the latter species pupated gregariously on the haustorium while those of *D. harpalyce* remained on the foliage. Although orange *D. harpalyce* pupae in summer took less than half the time to complete development than black pupae did in winter (72-75 days max.), the pupal stage of this form is comparatively longer than that recorded for other *Delias* species viz: *D. aganippe* (17 days in January at Eltham, pers. obs.), *D. argenthona* (10 days at 24°C, Braby, unpubl. data), *D. nigrina* (8 days at 27°C to 16 days at 19°C, Nousala 1979), and *D. ennia nigidius* (9 days in August at Kuranda, Quick 1982a).

Pupal polyphenism

The variability in pupal colour is intriguing and the two broad colour forms are clearly seasonally linked. Larvae which pupate in winter are at first bright reddish in colour, a finding previously noted by McCubbin (1971), but after several days the pupae usually become black. Limited field and laboratory observations on late instar larvae and pre-pupae in summer showed that cool temperatures promote forms which are dark reddish with some black, rather than the typical bright orange form (Braby, unpubl. data). More studies are needed to determine precisely which environmental factors cause differential pupal colour.

Polyphenism in butterflies (the existence of environmentally cued alternative phenotypes in a population) is generally viewed as a highly adaptive evolutionary response to environmental seasonality (Shapiro 1984), and the significance of melanism in wing pigmentation of several butterfly species has been shown to play an important adaptive role in thermoregulation (e.g. Watt 1968). A similar mechanism may operate in the pupal colours of *D. harpalyce* in which the black pupal morph may have evolved as a means of tolerating the harsh cold winter periods of south-eastern Australia. Given that *D. harpalyce* is the only Australian species in the genus which has a predominantly black pupa (other species are mainly orange or yellow, although winter melanism has recently been recorded in *D. argenthona*, Braby, unpubl. data) and which also has a strictly temperate distribution, it seems likely that the black pupal colour morph has developed as a 'cool-climate adaptation' or thermoregulatory device. Moreover, differences noted in web size and in locations of black and orange pupae between the seasons indeed suggests an adaptive behavioural response to seasonal differences in temperature. This behavioural, and presumed developmental plasticity may also explain why the species has a remarkably long flight season.

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