

**VOLTINISM OF *CALOPTERYX HAEMORRHOIDALIS* (VANDER LINDEN)  
IN THE SIERRA MORENA MOUNTAINS, SOUTHERN SPAIN  
(ZYGOPTERA: CALOPTERYGIDAE): A PRELIMINARY STUDY**

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## **Abstract**

Small sweep-net samples of larvae of *Calopteryx haemorrhoidalis*, obtained during five consecutive years from a permanent stream in the Sierra Morena Mountains, southern Spain, were combined according to month to infer the voltinism during the study period. Detailed records of head width, wing-sheath length and metamorphosis status for individual larvae are consistent with the population being mainly univoltine, a few individuals being semivoltine, and the life cycle being predominantly of the summer-species type.

## **Introduction**

*Calopteryx haemorrhoidalis* (Vander Linden) occurs in northern Africa, the Iberian Peninsula, southern France, parts of Italy and western Mediterranean islands (Askew 1988).

The stream where this study was made supported a small population of *C. haemorrhoidalis* and *Aeshna cyanea* (Müller) and larger populations of *Boyeria irene* (Fonscolombe), *Cordulegaster boltonii* (Donovan) and *Onychogomphus uncatatus* (Charpentier) (Ferreras-Romero 1994; Ferreras-Romero & Corbet 1995).

Sizes of samples obtained during this study were unavoidably small, closely reflecting the size of the population. Although small samples constitute a drawback when growth rates are being traced, this can be offset to a considerable extent by careful examination of the correlated size and condition of individual larvae (e.g. Johansson & Norling 1994; Ferreras-Romero & Corbet 1999), especially when results can be placed in context of key events in the life cycle. Applying this approach, we have been able to infer the voltinism of *C. haemorrhoidalis* in the study population during the period of investigation.

## Materials and methods

Bejarano Stream (37°56'N, 4°52'W; ca 400 m above m.s.l.) is near Sta. Maria de Trassierra, Córdoba, Andalusia, Spain, in the Sierra Morena Mountains. This small, fishless, permanent, mountain stream has a closed canopy of trees throughout most of its length. Alder (*Alnus glutinosa* (L.)), chestnut (*Castanea sativa* Miller), elm (*Ulmus minor* Miller), and hazel (*Corylus avellana* L.) grow along the banks. At the sampling site the stream's width was 2-5 m and its mean water depth was 35-50 cm. On 13 June 1990 properties of the water were: conductivity 0.5 mmhos/cm;  $\text{HCO}_3^-$  303.78 mg/l;  $\text{SO}_4^{2-}$  55.68 mg/l;  $\text{CO}_3^{2-}$  30.18 mg/l;  $\text{Cl}^-$  14.90 mg/l;  $\text{Ca}^{2+}$  (soluble) 77.66 mg/l;  $\text{Mg}^{2+}$  24.12 mg/l;  $\text{Na}^+$  11.73 mg/l; and  $\text{K}^+$  0.39 mg/l.

From May 1988 through May 1992, larvae (of *C. haemorrhoidalis*) were collected monthly (except in November 1989) by hand nets (mesh size measured along one side of a square = 0.25 mm); larvae were also collected in February 1988 and October 1992. Because larvae below a certain size are not adequately sampled by nets of the mesh size we used (see Lawton 1970), the frequency of small larvae will have been underestimated, for example during and after egg hatching (see Johnson 1986). During the emergence period in spring and summer final-stadium exuviae were collected in 1990 through 1992, but exhaustively and systematically only in 1992 (Ferrerías-Romero & Corbet 1995); and in 1992 the presence of adults was also recorded. At each visit water temperature, measured to the nearest 1/2 °C, was recorded between 0900 and 1100 h solar time. Stadia are designated according to the convention F-0 (final), F-1 (penultimate), F-2 (antepenultimate) and so on.

In the laboratory the head width (maximum distance across the compound eyes) and the length of the metathoracic wing sheaths of each larva collected were measured to the nearest 0.08 mm, using a Wild binocular microscope with an eyepiece micrometer; the number of abdominal segments overlain by the metathoracic wing sheath was also recorded. The sex of each larva, except those with a head width <1.5 mm (namely ca stadium F-5 or earlier) was determined according to the presence or absence of gonapophyses on the ventral surface of abdominal segments 8 and 9. Larvae in the three last stadia were assigned to stadia by means of wing-sheath length and when necessary head width.

Signs of metamorphosis in F-0 larvae were detected in the external appearance of the head (compound eyes, ocelli, prementum of labium) and wing sheaths (see Corbet & Prosser 1986). We deemed metamorphosis to have begun when the dark pigmented area of the compound eyes extended mesially to the base of each antenna. When metamorphosis is advanced, the pigmented area of the compound eyes is more extensive, the ocelli (which hitherto have appeared as pale, oval patches) contract to become crescent-shaped, and the wing sheaths are swollen so that the fore wing sheaths are now completely visible when viewed dorsally, and the costal vein of the adult wing is visible, folded within the wing sheath.

From May 1988 through May 1992, 121 larvae were collected. The number of larvae collected in any single month is insufficient to reveal size-frequency distributions. By combining collections for a given month in consecutive years (a total of 48 net sweeps, plus two more in February 1988 and October 1992), clusters of size-frequency

distributions become apparent. Such combined data cannot provide information about year-to-year variation but, with the exercise of appropriate caution, can sometimes be used to infer patterns of voltinism (see Johnson 1986).

## Results and discussion

The highest water temperature ( $^{\circ}\text{C}$ ) recorded was 19 (21 August 1989, 4 September 1990, 3 and 18 August 1992) and the lowest was 10 (22 January 1992).

Stadium F-0 was unequivocally distinguished from the others by wing-sheath length (6.0–7.2 mm and reaching abdominal segment 4) and by head width (3.9–4.5 mm) (Fig. 1). The smallest F-0 larvae were found in May, June and July, and the largest in February (Fig. 2). In F-0, females were not found to be detectably larger than males. In F-1, the wing sheaths (2.9–3.6 mm) reach the posterior margin of abdominal segment 2, or even the anterior part of segment 3; and the head width is between 3.1 (larvae collected in April, May and July) and 3.6 mm (only in March), a range that overlaps with that in F-2. In F-2, the wing sheaths (1.6–2.4 mm) usually extend halfway along abdominal segment 2, and the head width (2.4–3.2 mm) is less during May through July and greater in November and December. In F-3, wing sheaths measure up to 1.7 mm (November to March) and the head width up to 2.6 mm (November and January). So wing-sheath length is reliable for distinguishing F-0 and F-1 but no other stadia,

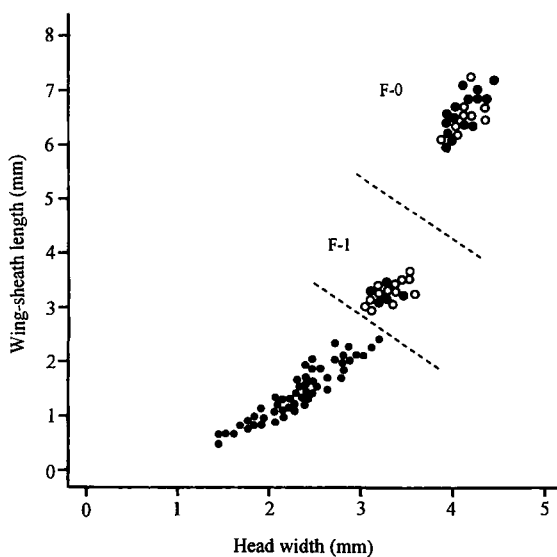


Figure 1. Relationship between head width and wing-sheath length of larvae of *Calopteryx haemorrhoidalis* collected during five consecutive years (1988–1992) at Bejarano Stream. For final (F-0) and penultimate (F-1) stadia: filled circles, males; empty circles, females.

even when this dimension is plotted against head width (Fig. 1). Only by considering the season (i.e. autumn-winter vs spring) when a larva was captured was it possible to assign it to stadium F-2 or F-3 among larvae of head width 2.4–2.6 mm and wing-sheath length 1.6–1.7 mm.

In summer in southern France eggs of *C. haemorrhoidalis* developed directly without interpolated dormancy (C. Schütte pers. comm.); and in northeastern Algeria eggs hatched 19 days after collection in nature in September (Benchallel 1994). By analogy with *Calopteryx virgo* (L.) (Robert 1958: 67), they can be assumed to hatch about two months after oviposition, namely in summer and autumn. The smallest larvae we encountered (head width < 1.5 mm) appeared from October to February (Fig. 2). As explained above, second-stadium larvae will have been under-represented due to the sampling technique. There is larval growth during autumn, winter and spring.

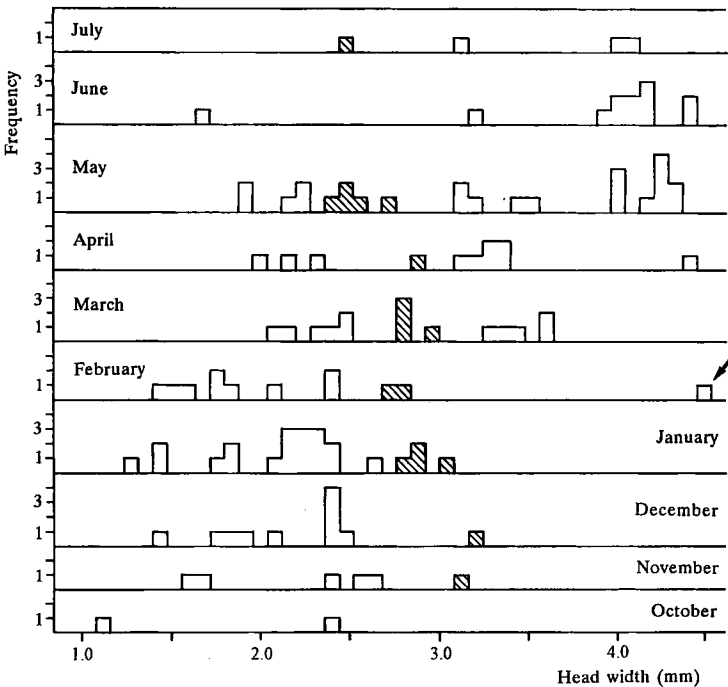


Figure 2. Size-frequency distributions for larvae of *Calopteryx haemorrhoidalis* at Bejarano Stream collected during five consecutive years (1988-1992). Results for all years have been combined according to month. Due to the mesh size of the collecting net, larvae with a head width < 1.5 mm are under-represented. Hatched area: larvae in the F-2 stadium. An arrow indicates the largest (F-0) larva, inferred to represent a semivoltine cohort. No larvae were collected during August and September of any year.

At the end of autumn (December) most larvae are in F-3 or earlier stadia; but the largest F-2 larvae (head width 3.1–3.2 mm) were found in November and December, possibly reflecting uninterrupted growth during summer and autumn. During early

winter, some larvae enter F-2. F-2 larvae collected in late spring are smaller (resembling in size F-3 larvae collected in autumn and winter), perhaps because growth in previous stadia was suppressed during winter (see Aoki 1999). Entry to F-1 and F-0 occurs mainly from March onwards.

Metamorphosis was detected only in spring and early summer: larvae exhibiting the first signs of metamorphosis appeared in early May (4 May 1990) and those exhibiting advanced metamorphosis were collected on 26 May 1988 and 12 June 1991.

During 1992 the seasonal pattern of emergence was quantified (Ferrerias-Romero & Corbet 1995), 10, 50 and 90% of the annual emergence being accomplished 22.3, 44.5 and 72.5% of the way through the emergence period; F-0 exuviae were collected from 14 June until 12 September. All occasional collections of exuviae during 1990 and 1991 fall within this period, except two exuviae found on 28 May 1991 and 4 June 1990.

In 1992, two males were seen perched near the stream on 20 May and one male on 25 May, but these were not necessarily autochthonous (see Cordero 1991). No adult was observed (in any year) until 24 June, peak numbers of mature adults occurring on 29 July (about 45) and 23 August (about 25). The latest adult (a female) was observed on 2 September (1992). These observations of adults are not inconsistent with results obtained by Cordero (1989) in northwestern Spain.

Having regard to the seasonal placement of egg hatch (late summer to early autumn), metamorphosis (May and June) and emergence (June through September), we infer the voltinism of the study population to be as follows. Most individuals are univoltine, but a few, developing slowly, spend a second winter in F-0, as indicated by the F-0 larva collected in February. (This individual had reached F-0 so much earlier [February or before] than all other larvae sampled [April to July] that a parsimonious inference would be that it was already in its second winter as a larva. This larva was, however, clearly exceptional.)

This inferred pattern of voltinism receives further support if the implications of alternative possibilities are examined. If a large proportion of the population were to be semivoltine, in July there would be a one-year old cohort of larvae (too large to have hatched from eggs laid in the same year and yet not large enough to emerge before the next year), whereas only the last three stadia are represented. Likewise, on the same assumption, there would be a strong presence of F-1 and F-0 larvae during winter, whereas, with one exception (the larva in February inferred to belong to a semivoltine cohort), such stadia are unrepresented.

If, as we believe, these inferences are well founded, the life cycle assumes this form. Most larvae, representing the univoltine component, grow 'fast' while a small minority grow slowly and are semivoltine. Larvae that grow fast may reach advanced stadia, even F-2, at the end of their first autumn, only 3–4 months after the eggs hatch. Such larvae then enter F-0 during the next spring and early summer, to emerge in their first summer, in the manner of univoltine 'summer species' (sensu Corbet 1954; see Corbet 1999:245). By contrast, larvae that grow slowly pass their second winter in F-0, in the manner of semivoltine 'spring' species. Cohort splitting into uni- and semivoltine components has been detected in two species of Zygoptera in England at ca 53°30'N (Parr 1970), where the semivoltine component was the larger. A population of

*Calopteryx virgo* in southern England at ca 50°53'N was mainly or entirely semivoltine (Corbet 1957).

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