

**FIRST RECORD OF A BIG-HEADED FLY, *EUDORYLAS ALTERNATUS* (CRESSON) (DIPTERA: PIPUNCULIDAE), REARED FROM THE SUBFAMILY CICADELLINAE (HOMOPTERA: CICADELLIDAE), WITH AN OVERVIEW OF PIPUNCULID-HOST ASSOCIATIONS IN THE NEARCTIC REGION**

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**Abstract**

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*Eudorylas alternatus* (Cresson) is recorded as a parasitoid of *Cuerna striata* (Walker) (Homoptera: Cicadellidae, Cicadellinae), providing the first known example of a big-headed fly parasitizing a cicadelline. Rearing methods and parasitism rates are discussed, and a summary of known Nearctic pipunculid-host associations is presented along with an overview of big-headed fly natural history.

Skevington, J., et S.A. Marshall. 1997. Le premier registre d'un pipunculid, *Eudorylas alternatus* (Cresson) (Diptera: Pipunculidae), élevé de la sousfamille Cicadellinae (Homoptera: Cicadellidae), avec un résumé des associations du pipunculid-hôte dans la région Nearctic. *The Canadian Entomologist* 129: 387–398.

**Résumé**

*Eudorylas alternatus* (Cresson) est attesté comme un parasitoïde de *Cuerna striata* (Walker) (Homoptera: Cicadellidae, Cicadellinae), pourvu la premier exemple de parasitisme d'un pipunculid sur un cicadelline. Méthodes d'élever et la taux de parasitisme sont discuté, et un résumé du Nearctic pipunculid-hôte associations reconnus est offert avec un résumé du pipunculid histoire naturelle.

**GENERAL INTRODUCTION**

Pipunculids, or big-headed flies, are exclusively parasitoids of leafhoppers and planthoppers (Homoptera: Auchenorrhyncha), including Cixiidae, Delphacidae, Flatidae, Cercopidae, Cicadellidae, Fulgoridae, and Membracidae. They attack host nymphs and adults in all groups except the Cercopidae, in which they attack only the adults (Waloff and Jervis 1987). Pipunculidae is the only family of Diptera that attacks Cicadellidae, preferring species of subfamilies Deltocephalinae and Typhlocybinae (Freitag 1985).

Over 1000 species of Pipunculidae have been described out of a probable world total of over 2000 species. Big-headed flies are found in almost every terrestrial habitat worldwide, but are most diverse in wet meadows and riparian and woodland edges. They are frequently collected by Malaise traps, emergence traps, pan traps, aerial suction traps, sweeping, and directly aspirating flies (De Meyer and De Bruyn 1989; Waloff 1975; Whittaker 1969). Different trapping methods likely capture somewhat different species (De Meyer and De Bruyn 1984). Adult pipunculids of both sexes feed on honeydew in the field (Jervis 1978; Williams 1918; Williams 1957) and, despite statements to the contrary (Williams 1957), they are attracted to artificial honeydew made of a mixture of honey and water (personal observation).

**NATURAL HISTORY AND REARING OF PIPUNCULIDAE**

**Introduction and Background**

The effects of pipunculid parasitization on hoppers have been documented by Chandra (1980), Giard (1889), Huq (1982), Lauterer (1981), Lindberg (1946), May (1979), Morcos (1953), Muir (1918), Perkins (1905), Remane and Schulz (1973), Ribaut (1936), Rothschild (1961), Vidano (1962), Waloff (1980), Whittaker (1969), Yano et al. (1985), and Yonen and Raatikainen (1984). Parasitized hoppers are sometimes recognizable by their swollen abdomen and sluggish movements. Jumping and walking are impaired by a

reduction in femur length and damage to the thoracic muscles and nervous system (May 1979). Abdominal color of hosts may become poorly pigmented, body size may be reduced or increased, and wing venation is often aberrant. Ovipositor length and the length of claspers in males are reduced in parasitized individuals. In female hosts, the development of ovarioles is halted and mature eggs are rarely found. Spermathecae and accessory glands are also lost. In males, the testes, spermathecal ducts, and a large part of the accessory gland are often lost. Only some males can copulate and fertilize females.

Despite these apparently obvious symptoms, it can be difficult to tell parasitized hoppers from gravid females. The degree of inactivity and swelling of the abdomens of some individual hoppers are clues that they are likely parasitized. The intersegmental membranes may also appear yellow as a result of the underlying pipunculid larva (as opposed to white). These differences may be obvious only near the completion of development of the parasitoid. Dissection is usually necessary to confirm that parasitization has occurred.

Emergence of the pipunculids occurs before or after the host's death (May 1979). Larvae force their way out with series of contractile movements over 5–10 min and emerge from any part of the abdomen, but most frequently from between the first and second abdominal tergites (May 1979). Males have a shorter period of pupal development than do females, and thus usually emerge first. The sex of the parasitoid is not influenced by host.

The lifespan of adults is 3–11 days (May 1979; Jervis 1980b; Huq 1986). Only Huq (1982, 1984) and Strübing (1957) have succeeded in establishing breeding populations in the lab, and then only for one summer.

The phenologies of 28 European species are known; most overwinter as diapausing pupae (18–19 of 23), although some (five to six of 23) overwinter as first-instar larvae within hosts (Waloff and Jervis 1987). Thirteen of 28 species are univoltine, 13–15 are bivoltine, and zero to two are trivoltine. With the exception of the apparently univoltine *Eudorylas alternatus* (Cresson), discussed below, phenologies of Nearctic species are entirely unknown.

Data on host range are available for more than 52 European species of Pipunculidae. In the Nearctic region, only 13 species have received such documentation (Table 1). Previous catalogues of pipunculids and their hosts greatly overestimate the number of known associations. For example, Freytag (1985) produced a thorough, but partly speculative, list of worldwide leafhopper–pipunculid associations. Many of the associations are of limited value as they refer to presumed associations only. For example, Hardy (1943, 1953, 1954, 1963, 1964, 1967, 1971) frequently referred to hoppers seen "in association with" certain pipunculids. This is a useful starting point when attempting to discern host–parasitoid relationships, but is little more than a guess and can be misleading if included in a host–parasite catalogue. Nonetheless, with careful cross-referencing, Freytag's catalogue is useful. This is in contrast to the catalogue of pipunculid–host associations produced by Kapoor et al. (1987), in which almost every record has at least one error.

The host list for Nearctic pipunculids (Table 1) in the present work attempts to circumvent the above problems. Apart from possible misidentifications made by the initial authors, it is believed to be complete and represents only definitive host–parasitoid relationships.

Most big-headed flies are polyphagous, but show a preference for a particular set of host species. Only one species has been reared from more than one subfamily of host: *Cephalops obtusinervis* Zetterstedt (A. Albrecht unpublished, in Jervis 1980a). Occasionally, there may be more than one species of pipunculid per host (see below).

Rates of parasitism vary from fractions of a percent to 100% in local populations. Morakote and Yano (1990) found that the mean rate of parasitism by three species of pipunculids on *Nephotettix cincticeps* Uhler was 58.9% (100% parasitism was recorded in localized populations); Esaki and Hashimoto (1936) recorded 65% parasitism of *N. cincticeps*;

TABLE 1. Table of Nearctic pipunculids with known hosts\*

Pipunculid parasitoid	Homopteran host†	Country recorded in	Reference
1. <i>Cephalops (Semicephalops) varius</i> Cresson	Delphacidae: <i>Megamelus davisi</i> Van Duzee	USA	Wilson and McPherson 1981
2. <i>Chalarus latifrons</i> Hardy	Cicadellidae: Typhlocybinae: Empoascini: <i>Kybos butleri</i> (Edw.) <i>K. smaragdula</i> (Fall.)	England England	Jervis 1980a, 1992 Jervis 1980a, 1992
3. <i>Chalarus spurius</i> (Fall.)‡	Typhlocybini: <i>Eupteryx cyclops</i> (Matsumura) <i>E. aurata</i> (L.) <i>E. urticae</i> (Fab.)	Wales Wales, France Wales, France	Jervis 1992 Jarvis 1980a, 1992 Jervis 1980a, 1992
4. <i>Dorylomorpha (Dorylomyza) tridentata</i> Hardy	Deltocephalinae: Athyasanini: <i>Thumnotettix</i> spp.	England	Waloff 1975
5. <i>D. (Dorylomyza) xanthopus</i> (Thomson)	<i>Conosanus obsoletus</i> (Kirs.) <i>Euscelis obsoletus</i> (Kirs.) Paralimnini: <i>Arthuldeus pascuellus</i> (Fall.) <i>Diplocolemus bensoni</i> (China) <i>Psammotettix confinis</i> (Dahl.) <i>Verdanus abdominalis</i> (Fab.)	England England Germany England England England	Waloff 1975; Benton 1975 Waloff 1980 Lauterer, pers. comm. in Albrecht 1990 Waloff 1980 Waloff 1980; Benton 1975 Waloff 1980; Benton 1975
6. <i>Eudorylus aequus</i> (Cresson)	Deltocephalini: <i>Graminella nigrifrons</i> (Forbes)	USA	Freytag 1985
7. <i>E. alconatus</i> (Cresson)	Cicadellinae: Proconiini: <i>Cuerna striata</i> (Walker)	Canada	New record
8. <i>Metadorylus subopacus</i> (Loew)§	Deltocephalinae: Scaphytopiini: <i>Scaphytopius acutus</i> (Say)	USA	Hardy 1964 in Freytag 1985
9. <i>M. subopacus industrius</i> (Knab)	Opsiiini: <i>Circulifer tenellus</i> (Baker)	USA	Hartung and Severin 1915; Hartung 1919; Severin 1924
10. <i>Pipunculus campestris</i> Latreille	Athyasanini: <i>Fuscelis incisus</i> (Kib.) <i>E. obsoletus</i> (Kirschbaum) <i>E. plebejus</i> (Fallén) Cicadulini: <i>Cicadula quadrinotata</i> (Fab.)	Germany England England Germany	Huq 1984 Waloff 1980 Waloff 1980 Coe 1966; Waloff 1980

	<i>Elymana sulphurella</i> (Zett.)	England	Waloff 1975
	<i>Macrostelus socialis</i> (Fl.)	Germany	Huq 1984
	<i>Graminella nigrifrons</i> (Forbes)	USA	Freytag 1985
	Macrostelini:		
	<i>Macrostelus laevis</i> (Ribaut)	Germany, Poland, England	Coe 1966; Bankowska 1973; Waloff 1980
	<i>M. sexnotatus</i> (Fallén)	England	Waloff 1980
	Paralimnini:		
	<i>Arthaldeus pascuellus</i> (Fallén)	Germany, England	Coe 1966; Waloff 1980
	<i>Diplocolenus bensoni</i> (China)	England	Waloff 1980
	<i>Errastunus ocellaris</i> (Fall.)	England	Waloff 1980
	<i>Mocuellus collinus</i> (Boh.)	Germany	Huq 1984
	<i>Psammotettix confinis</i> (Dahl.)	England	Waloff 1975
11. <i>Tomosvaryella appendipes</i> (Cresson)	Scaphytopiini:		
	<i>Scaphytopius nitridus</i> (DeLong)	USA	Pierce 1972
12. <i>T. subvirescens</i> (Loew)	Athysanini:		
	<i>Nephotettix cincticeps</i> Uhler	Thailand	Hardy 1971; Yano 1979
	<i>N. nigropictus</i> (Stal)	Thailand	Yano 1979
	<i>N. virescens</i> Distant	Thailand	Yano 1979
	Opsiini:		
	<i>Circulifer tenellus</i> Baker	Canada	Thompson 1951
	Cicadellinae:		
	Cicadellini:		
	<i>Graphocephala versuta</i> Say II	USA	Ashmead 1895
	Delphacidae:		
	<i>Nilparvata lugens</i> (Stal)	Taiwan	Chu and Hirashima 1981
13. <i>T. sylvatica</i> (Meigen)	Cicadellidae:		
	Deltocephalinae:		
	Athysanini:		
	<i>Nephotettix cincticeps</i> Uhler	Taiwan, Thailand	Hardy 1971; Yano 1979
	Deltocephalini:		
	<i>Graminella nigrifrons</i> (Forbes)	USA	Freytag 1985
	Macrostelini:		
	<i>Macrostelus quadrilineatus</i> (Forbes)§	USA	Hardy 1964
	Paralimnini:		
	<i>Arthaldeus pascuellus</i> (Fallén)	Poland, Germany, England	Coe 1966; Bankowska 1973; Waloff 1975
	<i>Diplocolenus bensoni</i> (China)	England	Waloff 1980
	<i>Errastunus ocellaris</i> (Fall.)	England	Waloff 1975
	<i>Jassargus pseudocellaris</i> (Flor.)	England	Waloff 1975
	<i>Psammotettix confinis</i> (Dahl.)	England	Waloff 1975
	<i>P. striatus</i> (L.)	Russia, Japan	Hardy 1971; Yano 1979
14. <i>T. vagabunda</i> (Knab)	Opsiini:		
	<i>Circulifer tenellus</i> (Baker)	USA	Hartung and Severin 1915; Hartung 1919; Severin 1924

15. <i>Verrallia virginica</i> Banks	Cercopidae: <i>Aphrophora suratogensis</i> (Fitch)	USA	Linnane and Osgood 1977
16. Unidentified Pipunculidae	Cicadellidae:	USA:	
	Agallinae:		
	Agalliini:		
	<i>Aceratagallia</i> spp.		Pierce 1972
	<i>Agallia constricta</i> VanDuzee		Freytag 1985
	Deltocephalinae:		
	Athysanini:		
	<i>Chlorotettix spatulatus</i> (Osborn and Ball)		Baldrige and Blocker 1980
	<i>Colladonus</i> spp.		Pierce 1972
	<i>Exitianus exitosus</i> (Uhler)		Blocker et al. 1972; Baldrige and Blocker 1980
	Deltocephalini:		
	<i>Amblysellus curtisii</i> (Fitch)		Freytag 1985
	<i>Endria inimica</i> (Say)		Freytag 1985
	<i>Flexamia atlantica</i> (DeLong)		Blocker et al. 1972; Baldrige and Blocker 1980
	<i>F. picta</i> (Osborn)		Baldrige and Blocker 1980
	<i>Graminella mohri</i> DeLong		Blocker et al. 1972; Baldrige and Blocker 1980
	<i>Laevicephalus parvulus</i> (Gillette)		Blocker et al. 1972; Baldrige and Blocker 1980
	<i>Laevicephalus</i> spp.		Baldrige and Blocker 1980
	<i>Latalus sayi</i> (Fitch)		Freytag 1985
	<i>Planicephalus flavicostus</i> (Stal)		Freytag 1985
	Doraturini:		
	<i>Athysanella argenteola</i> (Uhler)		Baldrige and Blocker 1980
	<i>A. attenuata</i> Baker		Blocker et al. 1972; Baldrige and Blocker 1980
	<i>A. emarginata</i> (Osborn)		Blocker et al. 1972; Baldrige and Blocker 1980
	<i>A. redacta</i> Blocker		Baldrige and Blocker 1980
	<i>Athysanella</i> spp.		Baldrige and Blocker 1980
	Hecalini:		
	<i>Parabolocratas</i> spp.		Baldrige and Blocker 1980
	Macrostelini:		
	<i>Macrostelus fascifrons</i> (Stal)		Baldrige and Blocker 1980
	<i>M. quadrilineatus</i> (Forbes)		Baldrige and Blocker 1980
	Paralimnini:		
	<i>Mocuellus caprillus</i> Ross and Hamilton		Blocker et al. 1972
	<i>M. collinus</i> (Boheman)		Baldrige and Blocker 1980
	<i>Psammotettix lividellus</i> (Zetterstedt)		Freytag 1985
	<i>Psammotettix</i> spp.		Freytag 1985

Stenometepeini:		
<i>Chal. atropunctata</i> (Gillette)		Baldrige and Blocker 1980 Freytag 1985
<i>Strellus bicolor</i> (VanDuzee)		
Typhlocybinae		
Dikraneurini:		
<i>Dikraneura</i> spp.		Freytag 1985
<i>Forcipata loca</i> DeLong and Caldwell		Freytag 1985
Erythroneurini:		
<i>Erythroneura comes</i> (Say)		Thompson 1951

\*Host records for Holarctic species of big-headed flies are included from regions outside of North America to indicate what the parasitoids might attack in the Nearctic.

†Higher taxonomy conforms to Oman et al. (1990).

‡In his revision of *Chalarus*, Jervis (1992) discovered that *C. spumarius* is part of a species complex. Former host records applied to a number of species within this complex, and *C. spumarius* was found to be exclusively parasitic on *Euphyas* leafhoppers. Additionally, the status of *C. spumarius* in North America was questioned and will remain in doubt until it is clarified by a Nearctic revision.

§Relationship questionable, original reference not seen by present authors.

||Ashmead (1895) states that he believes that *T. subobscurus* is parasitic on *G. versata*. What he bases this belief on is not clear. As a result, this record should be considered with apprehension.

Whittaker (1969) discovered that 37% of *Philaenus spumarius* (L.) were parasitized by *Verrallia aucta* Fallén over a 4-year period, whereas the alternate host, *Neophilaenus lineatus* (L.), suffered 25% parasitism in the same period; Hartung and Severin (1915) found *Eutettix tenellus* Baker with up to 47% parasitism by *Eudorylus subopacus industrius* Knab and *Tomosvaryella vagabunda* (Knab); and Linnane and Osgood (1977) found that fewer than 8% of *Aphrophora saratogensis* (Fitch) were parasitized by *Verrallia virginica* Banks, although 60% were parasitized in one plantation.

The role of pipunculids in the natural regulation of hopper numbers is indisputably important. Despite this recognized importance, few studies have documented the magnitude of their impact on host populations. Whittaker (1973) performed elegant studies on the interaction of one species of pipunculid and its host, in which *V. aucta* was found to attack *P. spumarius* and *N. lineatus* more or less in proportion to their abundance. Each host species was suspected to act as a reservoir for the parasitoid in years when the other host was less abundant. *Philaenus spumarius* has stable populations in England, but is a pest in North America where *V. aucta* is absent (Thompson 1977; Weaver and King 1954). Weaver and King (1954) state that *P. spumarius* occurs throughout most of the Holarctic region and is a pest in eastern North America where this status is generally attributed to favourable climatic conditions and agricultural regimes. There may be other reasons for *P. spumarius* becoming a pest. Whittaker (1973) suggests that if *P. spumarius* reached the New World by being transported as overwintering eggs in straw stubble, then it would have been practically impossible for *V. aucta*, which pupates in the ground in the winter, to travel with its host. If populations of *P. spumarius* in North America lack the density-dependent mortality of the nymphs and the compensating action of *V. aucta* in the subsequent adult stage, they may be highly unstable (Whittaker 1973). Whittaker (1969) suggested that *V. aucta* is a good candidate for biological control, especially where its alternate host, *N. lineatus*, occurs. Remarkably, to date no such introduction has been attempted.

The potential value of the Pipunculidae for biological control has stimulated some work on the bionomics of this family. For example, recent research into the control of the potato leafhopper, *Empoasca fabae* (Harris), a major pest of alfalfa in the midwestern and eastern United States and Canada, involved exploration within Europe for natural enemies to be introduced to the United States (Jervis 1992) and included rearing of *Chalarus* for release. Similarly, European species of Pipunculidae are being considered for introduction into New

Zealand for control of Frogatt's apple leafhopper, *Edwardsiana crataegi* (Douglas), populations of which are showing insecticide resistance (Jervis 1992).

The very high rates of parasitism reported here for *E. alternatus*, which we newly record as a parasitoid of *Cuerna striata* Walker, suggests that Pipunculidae are crucial in controlling hopper numbers and that this relatively poorly known group of flies has significant economic potential.

Hoppers of the genus *Cuerna* all feed on herbaceous plants as nymphs (Beirne 1956). The food plants of *C. striata* are unknown but it appears that this hopper feeds on grasses (Hamilton 1970). This species is of no economic importance, unlike its relatives *C. costalis* (F.), *C. occidentalis* (Oman and Beamer), and *C. yuccae* (Oman and Beamer). *Cuerna costalis* is one of most important vectors of phony peach disease (Turner 1949). *Cuerna costalis*, *C. occidentalis*, and *C. yuccae* are minor vectors of Pierce's disease of grape (Frazier 1944; Freitag et al. 1952; Kaloostian et al. 1962). Further research into *E. alternatus* and its habits may be relevant to biocontrol.

### Materials and Methods

Various methods have been devised for rearing Pipunculidae from parasitized hosts (see Benton 1975; Coe 1966; Huq 1982; Jervis 1978, 1980b; May 1979; Strübing 1957; Waloff 1975; Whittaker 1969). Chandra (1978, 1980) and Freytag (1988) describe methods for rearing Dryinidae which may prove suitable for Pipunculidae. Freytag's method appears to be excellent for use when the host's food plant is known, but methods described by Mitsuhashi (1979) are more appropriate when the host's food plant is unknown. Mitsuhashi's approach, essentially the same as Fife (1932), May (1979), Mittler and Dadd (1964), and Whittaker (1969), is followed here as described below.

Hoppers were first dissected to determine which species were parasitized. This involved removing the abdomen of freshly killed hoppers and squeezing the contents out by holding the tip of the abdomen with a needle and pushing a probe up from the tip to the base of the abdomen. When parasitized *C. striata* were discovered, live specimens were collected and reared (see Table 2 for collection dates and localities). Hoppers were kept in clear plastic vials 0.50 cm long and 0.27 cm in diameter. Moist cotton was placed in the vials to maintain high humidity and three to four hoppers were added. Vials were covered with a layer of parafilm, stretched as thin as possible without breaking. Three drops of a fresh 10% sucrose solution were placed on the parafilm and another layer of parafilm was stretched over it (thus forming a food-filled membrane); hoppers pierced the bottom layer of parafilm to feed on the sucrose solution. The sucrose solution and moist cotton were changed every 2 days. Most hoppers kept in this manner survived for over 8 days, long enough for the parasitoids to emerge if last-instar hoppers had been collected.

Addition of sucrose solution is not necessary if hoppers are observed at intervals in the field and are collected for rearing only when parasitoids are fully developed. In this way, hoppers can be maintained for 3 or 4 days without food until most parasitoids have emerged.

After forming puparia, parasitoids were transferred to other 0.50- by 0.27-cm tubes containing a mix of peat and sand (50:50). Pieces of toothpicks were stuck into the soil mixture to give the emerging pipunculids a place to perch and dry their wings. The peaty substrate was moistened and the vials were covered with fine mesh screening and placed in a closed plastic box containing 1 cm of saturated sand in the bottom (to maintain high humidity). Puparia were maintained at 18–22°C (room temperature) until the adult flies emerged. Light conditions varied with lab activities and were not regulated. Adults were allowed to dry themselves for 12–24 h before they were killed with potassium cyanide. Adults were then glued to paper points, labelled, and placed in the University of Guelph collection.

TABLE 2. Percentage parasitism of *Cuerna striata* Walker by *Eudorylus alternatus* (Cresson)\*

Date collected	Location†	Number of hoppers parasitized by pipunculids	Total number of hoppers examined	Percentage parasitism
7 May 1992	2 km East of Arkell	43	138	31.2%
29 March 1993	Fergus	6	47	12.8%
27 April 1993	2 km E of Arkell	13	28	46.4%
27 April 1993	5 km SE of Arkell	64	80	80.0%
13 May 1993	Victoria Rd., 4 km S of Guelph	6	11	54.5%
4 May 1994	5 km SE of Arkell	71	80	88.8%

\*Voucher specimens of *C. striata* and *E. alternatus* are marked with diagnostic yellow labels and are deposited in the University of Guelph insect collection (Guelph, Ontario, Canada).

† All specimens were collected in Wellington County, Ontario, Canada.

‡ Rate determined by rearing; no dissections.

§ Rate determined by dissection of larvae.

Larvae of all sizes were collected when determining parasitism rates and were preserved in 70% alcohol and placed in the University of Guelph collection. They were immersed alive into the alcohol, or were first immersed in 80°C water to extend them fully, followed by preservation in 70% ethanol (as in May 1979).

Identification of specimens of *Cuerna* was accomplished using Hamilton's (1970) key to Canadian members of the genus.

### Results

Research focussed on the discovery of *E. alternatus* in adult *C. striata* (Homoptera: Cicadellidae, Cicadellinae, Proconiini).

In 1992, one pipunculid emerged and formed a puparium on 2–4 May from a hopper collected on 28 April. An adult fly eclosed from the puparium on 22 May (18–20 days development). The remainder of the rearing in 1992 was carried out on 138 hoppers collected on 7 May (Table 2). Forty-three larval pipunculids emerged from the hosts and formed puparia between 9 and 13 May (two of the 43 specimens were collected into alcohol). Nineteen adults (46.3%) eclosed from these puparia between 1 and 5 June. The average time from pupariation until emergence at 18–22°C was 22.2 days (minimum 20; maximum 25). Separate determinations were not made for males and females.

In 1993, rearing was carried out on 39 of 80 *C. striata* collected on 27 April (Table 2). Temperature was not kept constant as in 1992. Larval parasitoids emerged from the hosts and formed puparia between 30 April and 5 May. Twenty-three puparia were obtained and were kept for rearing. Ten dead larvae were dissected from dead hosts and were stored in 70% alcohol. Nine adults eclosed from the 23 puparia (39.1%) between 20 and 27 May. Of these adults, six males emerged in 20–21 days and two females emerged in 22–24 days. One female was not noticed until later.

In 1994, 71 of 80 *C. striata* collected on 4 May were parasitized (Table 2). Larval parasitoids all emerged between 5 and 8 May. All larvae were collected into 70% ethanol.

In most cases, pipunculid larvae emerged from their hosts and pupariated in the rearing containers. Two live larvae and one puparium were dissected from dead hosts. After extraction, the larvae quickly formed puparia. All three of these puparia failed to develop.

Without exception, all pipunculid larvae emerged through the intersegmental membrane separating tergites 3 and 4 on the host hoppers.

Parasitism rates ranged from 12.8 and 88.8% depending on the location and date of collection (Table 2).



Six first-instar pipunculid larvae were dissected from hosts on 29 March 1993 and were collected into 70% alcohol. Additionally, 31 second-instar larvae collected on 27 April 1993 and six others collected on 13 May 1993 were placed in 70% alcohol.

The only other parasite encountered during this study was an adult female stylopid (Strepsiptera). It was dissected from an adult female *C. striata* collected 5 km SE of Arkell on 27 April 1993. The parasitized female hopper possessed a number of eggs, a situation not observed in specimens attacked by *E. alternatus*.

### Discussion

This is the first time that big-headed flies have been reared from a member of the subfamily Cicadellinae. The only other species of Cicadellinae suspected to be parasitized by pipunculids is *Graphocephala versuta* (Say). Ashmead (1895) believed that *Tomosvaryella subvirescens* (Loew) attacked this species but his suspicions were never confirmed by directly observed oviposition or through rearing trials.

Only one species of pipunculid, *E. alternatus*, was reared from *C. striata* during the course of this study. The specimens keyed out to *E. alternatus* with the only available keys to Nearctic species of *Eudorylas* by Hardy (1943) and Cresson (1911). Because these keys are based on variable characters and are supported by figures that are oversimplified and difficult to interpret, identification was supported by study of the type specimen of *E. alternatus*. Until *Eudorylas* is revised, identifications must be supported by direct comparison with type material.

Finding larvae of *E. alternatus* during dissections of overwintering hoppers in late March confirms that this species overwinters as first-instar larvae inside adult *C. striata*. As discussed in the introduction, this strategy is employed less often than overwintering as diapausing pupae.

From general collection data it appears that *C. striata* has only one generation per year. Given this, it is likely that *E. alternatus* is also univoltine, as is the case for most Pipunculidae.

Both the developmental time of the parasitoid and the emergence site of larvae fall within established parameters for the family. Records for duration of pupation of non-diapausing larvae vary from 13 to 30 days (De Meyer and De Bruyn 1989). Not surprisingly, development is temperature dependent (May 1979). Although May (1979) states that most larvae emerge between tergites 1 and 2, he also observed emergence between tergites 3 and 4.

Present results differ from those of Morakote and Yano (1988), who noted that the emergence of adult flies typically occurs only in morning hours (0400 to 0930). They recorded only two exceptions of flies emerging at dusk. In the present study, flies were observed emerging from their hosts throughout the day, and rarely at night, but this may be an artifact of variable light in the rearing regime.

The rates of parasitism recorded in this study (Table 2) are among the highest recorded for the family. Variability results from a number of factors. The parasitism rate calculated for 1992 trials was obtained without dissecting any hoppers. As a result, this rate is almost certainly artificially low as many parasitoids likely died within their hosts and were never detected. All 1993 rates were determined by dissection of hosts. The low rate for specimens collected in March may be a function of small sample size or the small larvae present in hosts at that time of year being overlooked.

Parasitism rates may differ because of site to site variation, but the difficulties of recording accurate rates should be recognized. Different activities of parasitized and non-parasitized hosts may affect collection efficiency. Yano et al. (1985) and Kathirithamby (1978) both concluded that flight behaviour of *N. cincticeps* is affected by parasitization by pipunculids, probably resulting from damage to the thoracic muscles, nervous system, and

poor physiological condition of the host. Parasitism rates calculated in the above studies varied according to the distance of light traps from fields because of the inactivity of parasitized hoppers. Sweeping may also bias the results of such studies. Parasitized hoppers are likely to be more easily swept in their inactive state. Conversely, they may be underestimated in sweep catches if they stay relatively immobile on or near the ground. Whittaker (1965) suggested using electric or hand pumps (such as a "D-vac") for determining parasitism rates and removing bias from the collection data. In the present study such a device was not available and *C. striata* were collected by first sweeping and then later aspirating all specimens present in an aggregation. Because of the tendency of *C. striata* to form dense aggregations, most specimens present in an aggregation could be collected in this manner, thus approximating the results of using a "D-vac" or some similar device. Another potential source of bias is the possibility that as winter aggregations of *Cuerna* break up in the spring, parasitized individuals remain behind, thus creating a misleadingly high level of parasitism for samples taken after late March. Despite the many potential problems in calculating the exact rates of parasitism, it is apparent that *E. alternatus* is an extremely important factor in the regulation of numbers of *C. striatus* in southern Ontario.

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