# Life history of *Neoplasta parahebes* (Diptera: Empididae: Hemerodromiinae)

**J. Robert Harkrider**

**Abstract**—The life history of *Neoplasta parahebes* MacDonald and Turner in a mountain stream in Southern California is reported. Female *N. parahebes* were separated from sympatric female *Neoplasta hebes* Melander by ovipositor morphology. Adults readily fed on adult midges (Diptera: Chironomidae) smaller than themselves. Ovarioles of gravid females contained an average of 74.8 eggs. Mating occurred in a unidirectional position. Females oviposited under the bark of submerged decaying wood. Eggs averaged 459 μm × 115 μm in size; most were laid within a 24 h period and, at room temperature, hatched in 10–11 days. There are three larval instars. Densities of larval *N. parahebes* were as high as 9.2 per 100 $cm^2$ of wood surface in submerged dead tree branches. Branches also contained larvae of *Orthocladius lignicola* Kieffer, a wood-boring chironomid; larval *N. parahebes* readily fed on the midge larvae in their tunnels. Pupation occurred in the decaying wood.

**Résumé**—Ce travail décrit le cycle biologique de *Neoplasta parahebes* MacDonald et Turner dans un cours d'eau de montagne du sud de la Californie. La morphologie de l'ovipositeur permet de séparer les femelles de *N. parahebes* de celles de *N. hebes* Melander qui vivent dans le même milieu. Les adultes se nourrissent volontiers de moucherons (Diptera : Chironomidae) de taille plus petite que la leur. Les ovarioles des femelles gravides contiennent en moyenne 74,8 œufs. L'accouplement se fait en position unidirectionnelle. Les femelles pondent sous l'écorce de bois submergé et en décomposition. Les œufs ont une taille moyenne de 459 μm × 115 μm; ils sont pour la plupart pondus sur une période de moins de 24 h et, à la température de la pièce, ils éclosent en 10–11 jours. Il y a trois stades larvaires. Les densités de larves de *N. parahebes* peuvent atteindre 9,2 par 100 $cm^2$ de surface de bois sur des branches submergées d'arbres morts. Les branches portent aussi des larves d'*Orthocladius lignicola* Kieffer, un chironomide mineur du bois; les larves de *N. parahebes* se nourrissent volontiers des larves du moucheron dans leur tunnel. La nymphose a lieu dans le bois en décomposition.

[Traduit par la Rédaction]

## Introduction

*Neoplasta parahebes* MacDonald and Turner (Diptera: Empididae: Hemerodromiinae), a small predaceous dance fly, occurs in western North America from southern British Columbia to southern California. The taxonomy of European Hemerodromiinae, based on adult morphology, is well known, but knowledge of the life history is incomplete (Wagner 1997). A similar situation exists in North America.

Species of *Neoplasta* Coquillett are found throughout the New World from Patagonia, Chile, and Brazil (Collin 1933; Smith 1962) to the United States of America and Canada (Melander 1927, 1947). Twelve species occur in North America, north of Mexico (MacDonald and Turner 1993). MacDonald and Harkrider (1999) used DNA analysis to associate adults and larvae of *Neoplasta* and differentiate the latter from larval *Metachela* Coquillett (Hemerodromiinae). Brammer *et al.* (2009) used the same technique to differentiate the immature stages of all four genera of Hemerodromiinae found in North America.

In spite of their wide distribution and occasional local abundance, the biology of *Neoplasta* species remains largely unknown. Adult emergence studies in Quebec indicated

Received 10 September 2010. Accepted 17 February 2011.

**J.R. Harkrider,** Biology Department, Cypress College, Cypress, California 90630, United States of America (e-mail: jhark@ix.netcom.com).
doi: 10.4039/n11-012

**Fig. 1.** San Antonio Creek, near Baldy Village, California, July 2005. Foreground shows the primary area of the creek for collecting *Neoplasta* between 1999 and 2003.

a preference by *N. scapularis* (Loew) for swift water (Harper 1980). Landry and Harper (1985) showed that immature *N. scapularis* are found in small and large streams in Quebec and that adults emerge over a 10 week period. Similar patterns were reported by MacDonald and Turner (1993).

Harkrider (2000*a*) found that 78% of adult *Neoplasta* collected along San Antonio Creek, a California mountain stream, were *N. parahebes*. In the only detailed study of immature aquatic empidids in North America, Harkrider (2000*b*) observed that larval *Neoplasta* are predators of larval *Rheotanytarsus* Bause (Diptera: Chironomidae) in that stream. The objective of the present study was to document the life history of *N. parahebes* at the California site.

## Materials and methods

### Study sites

The primary study site was a section of San Antonio Creek ("creek") approximately 300–350 m from the Mount Baldy Road bridge northeast of Baldy Village in the San Gabriel Mountains of southern California (Fig. 1; 1250 m, 34°14′25″N, 117°39′10″W). The surrounding vegetation was dominated by white alder (*Alnus rhombifolia* Nutt. (Betulaceae)) and California laurel trees (*Umbellularia californica* (Hook. and Arn.) Nutt. (Lauraceae)). This site had water year-round, although the creek is often dry above and below the primary study site during the summer. A second study site ("small stream") was a first-order stream fed from the spring, running year-round in alluvial deposits paralleling the west bank of San Antonio Creek (Fig. 2; Harkrider 2000*a*).

A third site ("Thurman Flats") was a seepage area in the San Bernadino Mountains along Highway 38, about 25 km east of San Bernardino (approximately 1030 m; 34°6′11″N, 117°0′46″W). The surrounding vegetation was dominated by white alder and California blackberry (*Rubus ursinus* Cham. and Schltdl. (Rosaceae)).

### Specimen collection and species separation

Adult *N. parahebes* were collected from stream-side vegetation at the creek and small stream sites with a sweep net and stored in four dram vials. Immature stages were collected by hand from rotting wood, midge

**Fig. 2.** Small spring-fed stream, adjacent to San Antonio Creek, near Baldy Village, California, June 2005. Many of the collections between 1999 and 2003 of eggs and larvae of *Neoplasta* were made in this area.

tubes, vegetation, and other materials in the water. For purposes of morphological comparison and species separation, adult *Neoplasta hebes* (Melander) were collected by sweeping vegetation at the Thurman Flats site. All specimens were stored on ice for return to the laboratory.

## Life history

Field-collected gravid female of *N. parahebes* were dissected under a microscope using No. 3 insect pins for the fecundity studies. Oviposition units consisted of a 450 mL base with a clear plastic 450 mL top as described in Sinclair and Harkrider (2004). Various objects, such as wet paper toweling, branches, or vegetation, were placed in the units to stimulate oviposition. Eggs were moved to Stentor dishes for incubation. Larval rearing units were 250 mL, open-top containers as described in Harkrider (2000*b*). Larvae of a *Rheotanytarsus* species or *Orthocladius lignicola* Kieffer from the creek collecting site were provided as prey.

Larval body, head complex (the sclerotized posterior tip of metacephalic rod to end of labrum), and eggs were measured using an ocular micrometer or by measuring digital images made with a dissecting or compound microscope and Motic Images 2000 (Windows XP version 1.2, 2000) software. Head capsule lengths of larval *N. scapularis* and *N. parahebes* were compared using a two sample *t* test.

In 1999 and 2000, emergent branches, 10–20 mm diameter and showing some evidence of deterioration, were collected from the small stream site near a resting site for adult *Neoplasta*. In the laboratory, the branches were systematically searched for eggs. Eggs were removed using dissection needles and moved to Stentor dishes for rearing.

In 2002, branches in contact with the cobble substrate, 5–28 mm diameter and showing signs of decay, were collected from the creek and small stream sites at 2-week intervals from January through September. In the laboratory, bark was removed and soft tissue was probed with dissection needles under a dissecting microscope. Presence of midge tunnels, midge larvae, empidid larvae, and other insects was recorded. In 2003, similar branch collections were made from the small stream site. In addition to the dissection of soft tissue, the branches were maintained in water without aeration for 24 h. The resulting reduced



https://doi.org/10.4039/n11-012 Published online by Cambridge University Press

oxygen tension caused many additional larval *Neoplasta* to emerge from midge tunnels in the wood.

Surface area of field-collected branches was estimated by calculating the surface area of a cylinder using branch diameter (measured at both ends) and length measurements. In all studies, live larvae were placed in rearing units. Damaged or surplus larvae were killed with hot water and preserved in 70% ethyl alcohol.

## Results and discussion

### Adults

#### *Species separation, phenology, and abundance*

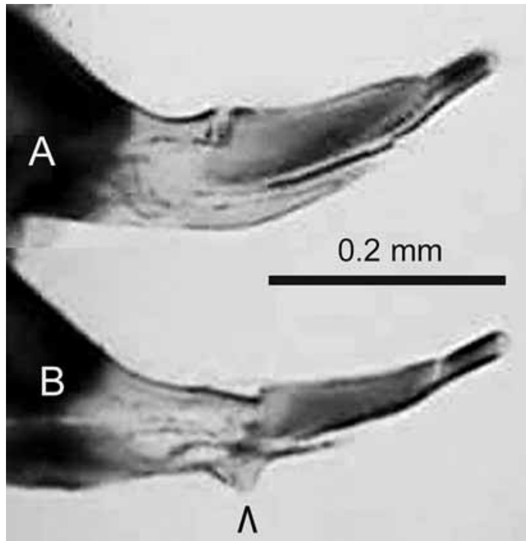
Harkrider (2000*a*) was unable to differentiate females of the two species of *Neoplasta* occurring at San Antonio Creek because diagnostic characters had not been described and the females "appear inseparable" (MacDonald and Turner 1993). Comparison of the dominant female type from this site with females collected during this study from Thurman Flats (where only *N. hebes* males were found) revealed that the ovipositor of *N. parahebes* is thinner at the proximal end and possesses a ventral keel-like structure (Fig. 3B) that is lacking in the ovipositor of *N. hebes*. Using the ovipositor diagnostic character, Harkrider's (2000*a*) original estimate of the relative abundance of *N. parahebes* at San Antonio Creek has been slightly revised to 75% of aquatic empidids.

Some adult male *N. parahebes* were found as early as March, and a few individuals remained until December. The greatest abundance of adults occurred from May to July; male abundance peaked in early May, and female abundance peaked in July.

#### *Mating*

Mating pairs of *N. parahebes* were observed twice. A pair was observed *in copula* on the leaves of a California laurel tree above the small stream on a June morning. A second pair was observed *in copula* in a rearing unit after having been captured that day. In both cases, the mated pairs were oriented unidirectionally with the male above the female as described by McAlpine (1981). The female of the captured pair stood on a ledge of the rearing unit with the male grasping her, his head above her thorax. The female

**Fig. 3.** Ovipositors of *Neoplasta hebes* (A) and *N. parahebes* (B). Arrow indicates the keel-like structure characteristic of ovipositors of *N. parahebes*.




shook violently with a yawing motion for 2–3 s, and then stopped for 4–10 s before shaking again. This behaviour continued for about 3 min and was subsequently repeated, though shorter in duration, four times during the next 36 min. All movements were abrupt and the pair was usually motionless between movements (the female occasionally turned or moved short distances). After the pair broke apart, they oriented face to face, less than a body length apart, for a second or two. The male then flew away and no further interaction was observed.

#### *Feeding*

Adult *N. parahebes* were observed in 8 or 16 dram vials with conspecifics, adult *N. scapularis*, and various potential prey items collected from the same habitat. Cannibalism was never observed between adults of *N. parahebes*, but in one instance, a male *N. scapularis* fed on a male *N. parahebes*. In all instances where feeding by adult *N. parahebes* was observed, the prey were midges that were smaller than the adult empidid.

#### *Oviposition*

In June and July of 1999 and 2000, 29 branches were collected. Of these, 11 had



https://doi.org/10.4039/n11-012 Published online by Cambridge University Press

eggs deposited in cracks or under loose bark; the eggs were not visible without removing the covering bark or debris. Egg density ranged from 1.3 to 47.8 eggs/cm$^2$ of the branch surface. Eggs were deposited in small clusters or individually over a wide area. Eggs did not occur under bark still firmly attached to the wood beneath. Most eggs were deposited on submerged sections of the branches.

Initial attempts to induce oviposition of gravid females in rearing units failed. Most potential oviposition substrates, as well as strategies such as decapitation of gravid females (Cummings and Cooper 1993), failed to induce oviposition. However, decaying branches from the stream stimulated oviposition and resulted in egg deposits similar to those on field collected branches.

In the laboratory, a female of *N. parahebes* laid most of her eggs underwater within a 24 h period, although actual oviposition was not observed. Dissection of 10 gravid females revealed a range of 62–88 mature ovarioles (average 74.8). Dissected females in early stages of egg development showed as many as 96 ovarioles.

## Immatures

### *Eggs*

Length of 30 eggs laid by three females in a rearing unit ranged from 418 to 502 µm (average 459 µm). Width ranged from 106 to 124 µm (average 115 µm). Eggs collected in rearing units and held in Stentor dishes produced larvae within 9–11 days at room temperature.

### *Larval development*

Length of newly hatched *N. parahebes* larvae ranged from 600 to 800 µm (720 ± 90 µm, $n$ = 10); length of head complex ranged from 160 to 170 µm (163 ± 3 µm, $n$ = 10). The newly hatched larvae would not feed and all died within 2 or 3 days. Thus, cannibalistic behaviour common in later stages was not observed.

Harkrider (2000*b*) suggested that the head complex of the last instar larva of *N. scapularis* was significantly larger than that of *N. parahebes*, but this was based on only one specimen of *N. scapularis*. In the current study, lengths of the head complex of last instar exuviae from reared specimens of *N. scapularis* (580 ± 20 µm, $n$ = 10) and *N. parahebes* (545 ± 28 µm, $n$ = 10) were significantly different ($t$ = 3.63, $P$ = 00.0019, df = 18).

There appear to be three larval instars in *N. parahebes*. Harkrider (2000*b*) noted two head complex size classes in larval *Neoplasta* (0.50 mm and 0.30 mm). In the current study I plotted body length *versus* head complex length of larval *N. parahebes* collected in three different years (Fig. 4). Some larvae longer than 4 mm were collected but were used for rearing and were not measured. Although it is not possible to identify larval *Neoplasta* to species and thus, more than one species may be represented in the data, three distinct head length groups are evident: 0.16–0.18 mm ($n$ = 3), 0.30–0.35 mm ($n$ = 15), and 0.50–0.60 mm ($n$ = 24).

Cummings and Cooper (1993) reported three larval instars for tachydromiine empidids and Sinclair and Harkrider (2004) suspected the presence of three larval instars for *Roederiodes wirthi* Chillcott (Clinocerinae). A larval *Neoplasta* field collected in July 2004 had a head complex measuring 0.16 mm; it molted 2 days later to a larva with a head complex of 0.30 mm. These measurements agreed with the first two size classes (instars) suggested in Figure 4. The data reported here support the hypothesis that three larval instars occur in *Neoplasta*.

### *Larval habitat*

Harkrider (2000*b*) recorded larval *Neoplasta* in larval tubes of *Rheotanytarsus* midges, but a search for other larval habitats was not successful. In 1999, eggs, larvae, and pupae of *Neoplasta* were found on emergent branches. From January through September 2002, larval densities were relatively similar on small stream and creek decaying branches (Fig. 5). Densities were highest at the start of the year, and from February through May, average density ranged from 1.8 to 2.5 larvae/100 cm$^2$ of branch surface area. A clear reduction in larval densities was observed in June, and from July to September, densities declined from 1.1 to 0 larvae/100 cm$^2$ of branch surface area. Reared adults indicated that *N. parahebes* and *N. scapularis* occurred at both sites.

During the 2002 survey, larval *Neoplasta* were strongly associated with larvae of the



https://doi.org/10.4039/n11-012 Published online by Cambridge University Press

**Fig. 4.** Head complex length plotted against total body length of preserved larvae of *Neoplasta*.

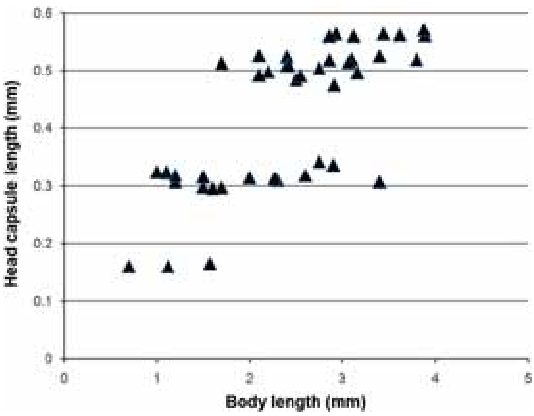
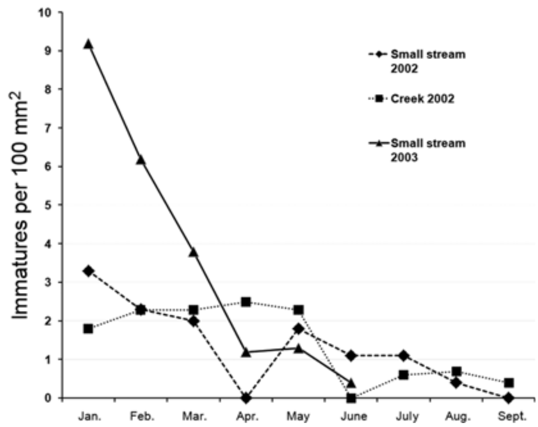



**Fig. 5.** Density of larval *Neoplasta* per 100 cm$^2$ of branch surface area collected from decaying branches sampled from streams near Baldy Village, California, during 2002 and 2003.




wood-boring midge *Orthocladius lignicola.* Only one larval *Neoplasta* was found in wood without evidence of *O. lignicola*. Larval *O. lignicola* burrow several millimeters into decaying wood, creating a pattern of tunnels in which larval *Neoplasta* can be found.

In 2003, 41% of larval *Neoplasta* collected in January came from samples of decaying branches held in water for 24 h without aeration after dissection to induce the larval empidids to vacate the midge tunnels. A large number of these larvae were small and would have been missed during the 2002 survey. The January maintenance of branches for 24 h without aeration yielded a total of 25 *Neoplasta* larvae (34% of all larvae collected in 2003). The January 2003 small stream branch samples produced 9.2 larvae/100 cm$^2$ (Fig. 5), nearly three times the density observed in January 2002. From January to April 2003, density of larval *Neoplasta* declined in the small stream branch samples, which is similar to the pattern observed in 2002.

The pattern of decline of the populations of larval *Neoplasta* is consistent with increasing numbers of pupae and consequent emergence of adult *Neoplasta* from May through July as observed by Harkrider (2000*a*). Cannibalism or migration of larvae to other habitats such as larval tubes of *Rheotanytarsus* midges could also be a factor.

Although 22 of 26 branches sampled in the first 3 months of 2003 contained larval *O. lignicola*, only 14 of the branches also contained larval *Neoplasta*.

### *Pupal habitat*

Harkrider (2000*b*) found no pupal *Neoplasta* in 4234 larval tubes of *Rheotanytarsus* midges. Five pupal *Neoplasta* were found in the 2002 survey of branches and 12 pupae were found within *O. lignicola* tunnels in the 2003 survey. The majority of adults reared from the 2002 and 2003 pupae were *N. parahebes* ($n$ = 12); the remainder were *N. scapularis* ($n$ = 4) and *N. hebes* ($n$ = 1). Most pupal *N. parahebes* were collected from March to May. Pupal collection and adult rearing data are consistent with adult emergence and species relative abundance reported by Harkrider (2000*a*). Harkrider (2000*a*) also suggested that the observed long flight period of *N. parahebes* was due to the long survival of adults. However, the collection of a single pupal *N. parahebes* in August 2003 suggests that an extended emergence period is more likely.

## Acknowledgements

I thank J.F. MacDonald (Purdue University, West Lafayette) who kindly reviewed an early version of the manuscript, Hans Meyer (Ökologie-Zentrum Christian-Albrechts-Universität zu Kiel) whose review was particularly helpful for data presentation, and Brad Sinclair (Canadian Food Inspection Agency, Ottawa, Ontario) whose review comments and encouragement were especially important.

## References

Brammer, C.A., Harkrider, J.R., and MacDonald, J.F. 2009. Differentiation of larvae and pupae of aquatic genera of Neartic Hemerodromiinae (Diptera: Empididae). Zootaxa, **2069**: 59–68.

Collin, J.E. 1933. Diptera of Patagonia and Southern Chile based mainly on material in the British Museum (Natural History). Part 4, Empididae. The Oxford University Press, Oxford, United Kingdom.

Cumming, J.M., and Cooper, B.E. 1993. Techniques for obtaining adult-associated immature stages of predacious tachydromiine flies (Diptera: Empidoidea), with implications for rearing and biocontrol. Entomological News, **104**: 93–101.

Harkrider, J.R. 2000*a*. Phenology of aquatic dance flies (Diptera: Empididae Hemerodromiinae) along a stream in Southern California. Pan-Pacific Entomologist, **76**: 170–175.

Harkrider, J.R. 2000*b*. Predation of larval *Neoplasta* Coquillett (Diptera: Empididae) on larval midges in the genus *Rheotanytarsus* Bause (Diptera: Chironomidae). Pan-Pacific Entomologist, **76**: 176–183.

Harper, P.P. 1980. Phenology and distribution of aquatic dance flies (Diptera: Empididae) in a Laurentian watershed. American Midland Naturalist, **104**: 110–117.

Landry, B., and Harper, P.P. 1985. The aquatic dance fly fauna of a subarctic river system in Québec, with the description of a new species of *Hemerodromia* (Diptera: Empididae). The Canadian Entomologist, **117**: 1379–1386.

MacDonald, J.F., and Harkrider, J.R. 1999. Differentiation of larvae of *Metachela* Coquillett and *Neoplasta* Coquillett (Diptera: Empididae; Hemerodromiinae) based on larval rearing, external morphology, and ribosomal DNA fragment size. Journal of the North American Benthological Society, **18**: 414–419.

MacDonald, J.F., and Turner, W.J. 1993. Review of the genus *Neoplasta* Coquillett of America north of Mexico (Diptera: Empididae; Hemerodromiinae). Proceedings of the Entomological Society of Washington, **95**: 351–376.

McAlpine, J.F. 1981. Morphology and terminology-adults. *In* Manual of Nearctic Diptera, vol 1. *Edited by* J.F. McAlpine, B.V. Peterson, G.E. Shewell, H.J. Teskey, J.R. Vockeroth, and D.W. Wood. Research Branch Agriculture Canada Monograph No. 27: Ottawa, Ontario. pp. 9–63.

Melander, A.L. 1927. Diptera, Family Empididae. *In* Genera Insectorum, fascicle 185. P. Wytsman. Louis Desmet-Verteneuil, Brussels, Belgium. pp. 1–434.

Melander, A.L. 1947. Synopsis of the Hemerodrominnae (Diptera, Empididae). Journal of the New York Entomological Society, **55**: 237–273.

Sinclair, B.J., and Harkrider, J.R. 2004. The immature stages and rearing observations of the aquatic dance fly, *Roederiodes wirthi* Chillcott (Diptera: Empididae: Clinocerinae), with taxonomic notes on the genus. Studia Dipterologica, **11**: 51–61.

Smith, K.G.V. 1962. Studies on the Brazilian Empididae (Diptera). Transactions of the Royal Entomological Society of London, **114**: 195–266.

Wagner, R.H. 1997. Diptera Empididae, Dance Flies. *In* Aquatic Insects of North Europe: a taxonomic handbook, Vol. **2**: *Edited by* A.N. Nilsson, Apollo Books, Stenstrup, Denmark. pp. 333–344.