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A METHOD FOR REARING PUPAE OF NET-WINGED MIDGES (DIPTERA: BLEPHARICERIDAE) AND OTHER TORRENTICOLOUS FLIES

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Abstract.—A method for obtaining reared adults of net-winged midges (Diptera: Blephariceridae) is presented. Rocks with attached pupae are removed from the stream and placed in a container maintained at high humidity. Survival and emergence rates exceeding 60% were recorded for several species of Nearctic *Blepharicera.* This method is ideal for associating pupae and adults of blepharicerids and other torrenticolous flies.

Key Words: net-winged midges, Blephariceridae, rearing, pupal-adult associations

Net-winged midges (Diptera: Blephariceridae) are a distinctive family of nematocerous flies whose immature stages are highly specialized for life in the cascades, rapids and waterfalls of mountain streams. Larvae show many adaptations to a torrenticolous life, including six ventral suckers and a cephalothorax (fused head, thorax, and first abdominal segment). The larvae of all species are grazers, using their highly modified mouthparts to feed on periphyton, the thin film of algae, bacteria, and other organic matter that occurs on current-exposed rocks. Pupae are equally adapted to torrential streams, being streamlined, somewhat dorsoventrally compressed, and attached immovably to rocks by ventrolateral adhesive discs. Adult blepharicerids are slender-bodied, long-legged and show a diversity of habits—some are insect predators, others are nectarivorous or non-feeding; most are short-lived and rarely venture beyond the riparian zone. In spite of these habits, net-winged midges may be a significant component to stream ecosystems (Georgian and Wallace 1983, Anderson 1992, Johns 1996). At many streams, particularly in waterfall habitats, these dipterans are not only the dominant grazer but one of the most abundant insects. The trophic importance of these flies has been under-appreciated, which reflects the paucity of abundance data and the difficulty in identifying larvae and pupae. Identification depends largely on our ability to associate these life stages with the adults. The purpose of this article is to describe an effective method for rearing pupae, thereby permitting association of pupae and adults.

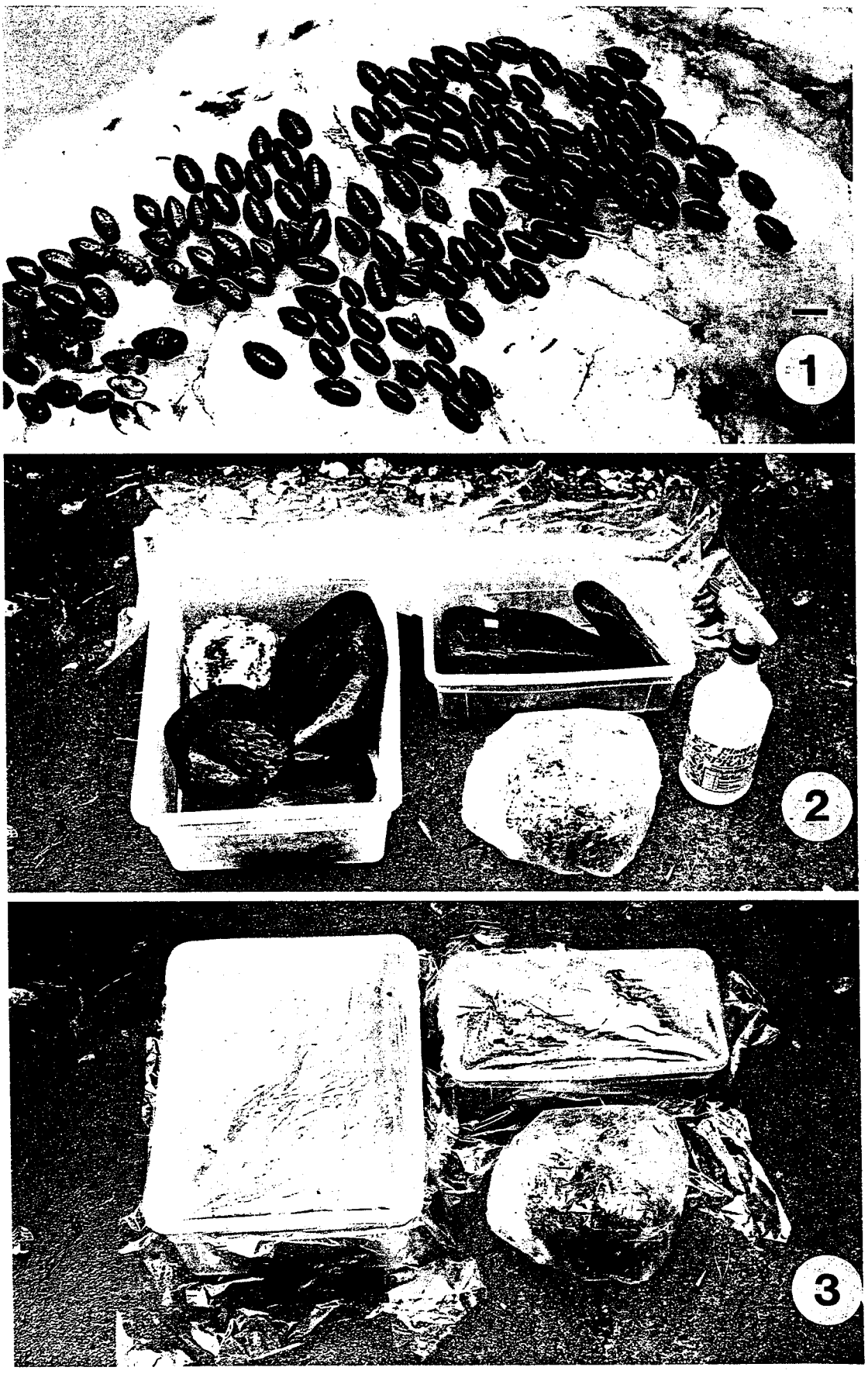
The Blephariceridae contain 26 genera and approximately 300 described species (Hogue and Zwick, in preparation), with representatives on most major continents. *Blepharicera* Macquart is one of the most widespread genera worldwide and in the Nearctic Region is the only group found in both western and eastern North America. Although past studies (e.g., Hogue 1978, Hogue and Georgian 1986) have provided significant insights about the eastern Nearctic fauna, several new species and distinct "morphotypes" of currently recognized species await description. Hogue (1987) provided detailed information about adult character systems, particularly male genitalia; however, the taxonomy of net-winged

midges has been hindered by lack of data on larvae and pupae, the stages encountered most often in faunistic and ecological studies and, consequently, the stages for which keys are needed most. A prerequisite for the identification of larvae, pupae, and adults of blepharicerids is the accurate association of all life stages. This is especially true of the eastern Nearctic fauna, which contains eight described species and at least that many undescribed species (Courtney, in progress). Within this complex, the larvae and pupae of three species (*B. capitata* Loew, *B. cherokea* Hogue, *B. diminutiva* Hogue) remain undescribed (Hogue 1987).

Recent studies of the Blephariceridae (Johns 1996, Courtney, in progress) and other stream-inhabiting Diptera (e.g., Courtney 1994) from eastern North America have led to significant new records of net-winged midges. These collections permit definitive association of the larvae, pupae and adults of all described and several new species of *Blepharicera*. Descriptions of and keys to larvae, pupae and adults of all Nearctic species will be provided in a separate paper.

In my studies of Nearctic net-winged midges, association of larvae and pupae has relied on the "ontogenetic" method (Hogue 1989), which involves dissection of a pharate later-instar from an earlier stage. Pupae and adults may be associated in a similar manner and, in some instances (e.g., for species restricted to bedrock habitats), this is the only feasible alternative. Ideally, association of pupae and adults is accomplished by pupal rearings. Detached pupae often survive when placed on damp filter paper in a loosely sealed, chilled container (e.g., petri dish in an ice-filled cooler), but in this state adults cannot emerge successfully—i.e. eclosion requires that the pupa be firmly attached to the substrate. The most effective method of obtaining reared adults involves collection of rocks with attached pupae (Fig. 1). Rocks should be removed from the stream, covered with a damp cloth or paper towels, and placed in an insulated container for transport to the laboratory. On arrival at the laboratory, rocks should be placed in a plastic container that holds a shallow layer of water, sufficiently deep to maintain high humidity but not cover the pupae (Fig. 2). The container is then sealed with a plastic sheet and oversized rubber band (Fig. 3). Alternatively, rocks can be placed in plastic bags. The rearing chamber should be opened 2–3 times per day to check for emerged adults, replenish the air supply, and moisten the pupae (using, for example, a standard spray-bottle for gardening).

Data from 1991–97 collections (Table 1) show survival and emergence rates of >60% for most species. Highest rates of survival occurred in *B. coweetae* Hogue and Georgian (79%) and *B. williamsae* Alexander (74%), species active early in the season, when thermal stress during transportation and rearing was probably less. Lowest rates of survival were in species active during late spring (e.g., *B. cherokea* Hogue) or summer (e.g., *B. similans* Johannsen). Data also indicate differences in male and female survival in some species, notably *B. cherokea*, which showed the lowest values for both males (60%) and females (49%). The basis for these gender differences is unclear. In some species, including *B. cherokea*, females emerge slightly later than males, which may increase the risk of thermal stress. Data in Table 1 are for specimens reared at room temperature (approximately 20°C). Higher rates of survival are expected for material reared at typical stream temperatures (<15°C). In spite of the possibility of some temperature-related mortality, data confirm that this rearing method is an effective means of associating pupae and adults of Appalachian blepharicerids. The same or similar methods have been used to rear pupae of Blephariceridae from Nepal, Thailand, and western North America, and of other torrenticolous Diptera (Courtney 1991).



Figs. 1–3. 1, Rock with attached pupae, mostly *Blepharicera cherokea* [scale bar approximately 3 mm]. 2–3, Rearing systems for Appalachian *Blepharicera*.

Table 1. 1991–97 data for pupal rearings of Appalachian *Blepharicera*. (e/d = number that emerged successfully/number that died; % = percent that emerged successfully).

Taxon	Males		Females		Total	
	e/d	%	e/d	%	e/d	%
B. appalachiae Hogue and Georgian	86/48	64	57/32	64	143/80	64
B. cherokea Hogue	137/90	60	44/45	49	181/135	57
B. coweetae Hogue and Georgian	48/11	81	26/9	74	74/20	79
B. similans Johannsen	177/91	66	74/46	62	251/137	65
B. tenuipes (Walker)	152/50	75	128/76	63	280/126	69
B. williamsae Alexander	62/24	72	40/11	78	102/35	74
Total	662/314	68	369/219	63	1141/595	66

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Literature Cited

Anderson, N. H. 1992. Influence of disturbance on insect communities in Pacific Northwest streams. Hydrobiologia 248: 79–82.

Courtney, G. W. 1991. Life history patterns of Nearctic mountain midges (Diptera: Deuterophlebiidae). Journal of the North American Benthological Society 10: 177–197.

Courtney, G. W. 1994. Biosystematics of the Nymphomyiidae (Insecta: Diptera): life history, morphology and phylogenetic relationships. Smithsonian Contributions to Zoology 550: 1–41.

Georgian, T. and J. B. Wallace. 1983. Seasonal production dynamics in a guild of periphyton-grazing insects in a southern Appalachian stream. Ecology 64: 1236–1248.

Hogue, C. L. 1978. The net-winged midges of eastern North America, with notes on new taxonomic characters in the family Blephariceridae (Diptera). Contributions in Science, Natural History Museum of Los Angeles County 291: 1–41.

Hogue, C. L. 1987. Blephariceridae. pp. 1–172 *In* Griffiths, G. C. D., ed., Flies of the Nearctic Region. Stuttgart: E. Scweizerbart'sche Verlagsbuchhandlung 2(4).

Hogue, C. L. 1989. The net-winged midge fauna (Diptera: Blephariceridae) of Antioquia Department, Colombia. Contributions in Science, Natural History Museum of Los Angeles County 413: 1–57.

Hogue, C. L. and T. Georgian 1986. Recent discoveries in the *Blepharicera tenuipes* group, including descriptions of two new species from Appalachia (Diptera: Blephariceridae). Contributions in Science, Natural History Museum of Los Angeles County 377: 1–20.

Hogue, C. L. and P. Zwick. In preparation. A synoptic catalog and bibliography of the Blephariceridae (Diptera) of the world.

Johns, J. A. 1996. The net-winged midges (Diptera: Blephariceridae) of the southeastern United States: phenology and ecology. M.Sc. Thesis, Clemson University, Clemson, South Carolina.