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REFERENCES CITED

ARNETT, R., AND P. A. SAMUELSON. 1986. The insect and spider collections of the world. Brill/Flora & Fauna Publications. Gainesville, Florida.

DEYRUP, M. A. 1981. Annotated list of Indiana Scolytidae (Coleoptera). Great Lakes Entomol. 14: 1-9.

DEYRUP, M. A. 1987. *Trischidias exigua* Wood, new to the United States, with notes on the biology of the genus. Coleopterists Bull. 41: 339-343.

HOPKINS, A. D. 1915. Classification of the Cryphalinae with descriptions of new genera and species. U.S. Dept. Agric. Rep. 99: 1-75, 4 pls.

PECK, S. B. 1989. A survey of insects of the Florida Keys: post-Pleistocene land-bridge islands: Introduction. Florida. Entomol. 72: 603-612.

WOOD, S. L. 1954. A revision of North American Cryphalini (Scolytidae: Coleoptera). Univ. Kansas Sci. Bull. 36: 959-1089.

WOOD, S. L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Great Basin Nat. Mem. 6: 1-1356.

WOOD, S. L. 1986. New synonymy and new species of American bark beetles (Coleoptera: Scolytidae), Part XI. Great Basin Nat. 46: 265-273.

WOOD, S. L., AND D. E. BRIGHT. 1992. A catalog of Scolytidae and Platypodidae (Coleoptera), Part 2: Taxonomic index Vol. B. Great Basin Nat. Mem. 13: 1-1553.

FUNCTION OF GILLS AND MESONOTAL SHIELD OF *BAETISCA ROGERSI* NYMPHS (EPHEMEROPTERA: BAETISCIDAE)

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ABSTRACT

The nymphs of Baetiscidae Banks (Ephemeroptera) possess a unique enlarged mesonotal shield which encloses the gills. The pattern of water circulation within this mesonotal chamber is described for *Baetisca rogersi* Berner. Suggestions are made on other functions of the shield.

Key Words: Mayflies, mesonotal chamber, respiration, morphology, nymphs, Ephemeroptera, *Baetisca*, gills.

RESUMEN

Las ninfas de *Baetiscidae* Banks (Ephemeroptera) poseen un escudo alargado en el mesonoto en el cual se encuentran las agallas. Se describe la forma de circulación del agua dentro de esta camara del mesonoto en *Baetisca rogersi* Berner. Se hacen sugerencias acerca de otras funciones del escudo.

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Mayfly nymphs of the families Baetiscidae and Prosopistomatidae are unusual in that they possess an enlarged mesonotal shield covering the thorax and most of the abdomen (Fig. 1). This shield forms a chamber (referred to here as the mesonotal chamber) which entirely encloses the gills.

In 1950 Berner described the entry of water into and out of the mesonotal chamber of *Baetisca* nymphs. Pescador & Peters (1974) reported briefly on the gill movements and water currents produced in the nymphs of *Baetisca rogersi* Berner in conjunction with a major paper on its life history and ecology. In the present study, observations were made concerning the path of water through the mesonotal chamber and over the gills of *B. rogersi.*

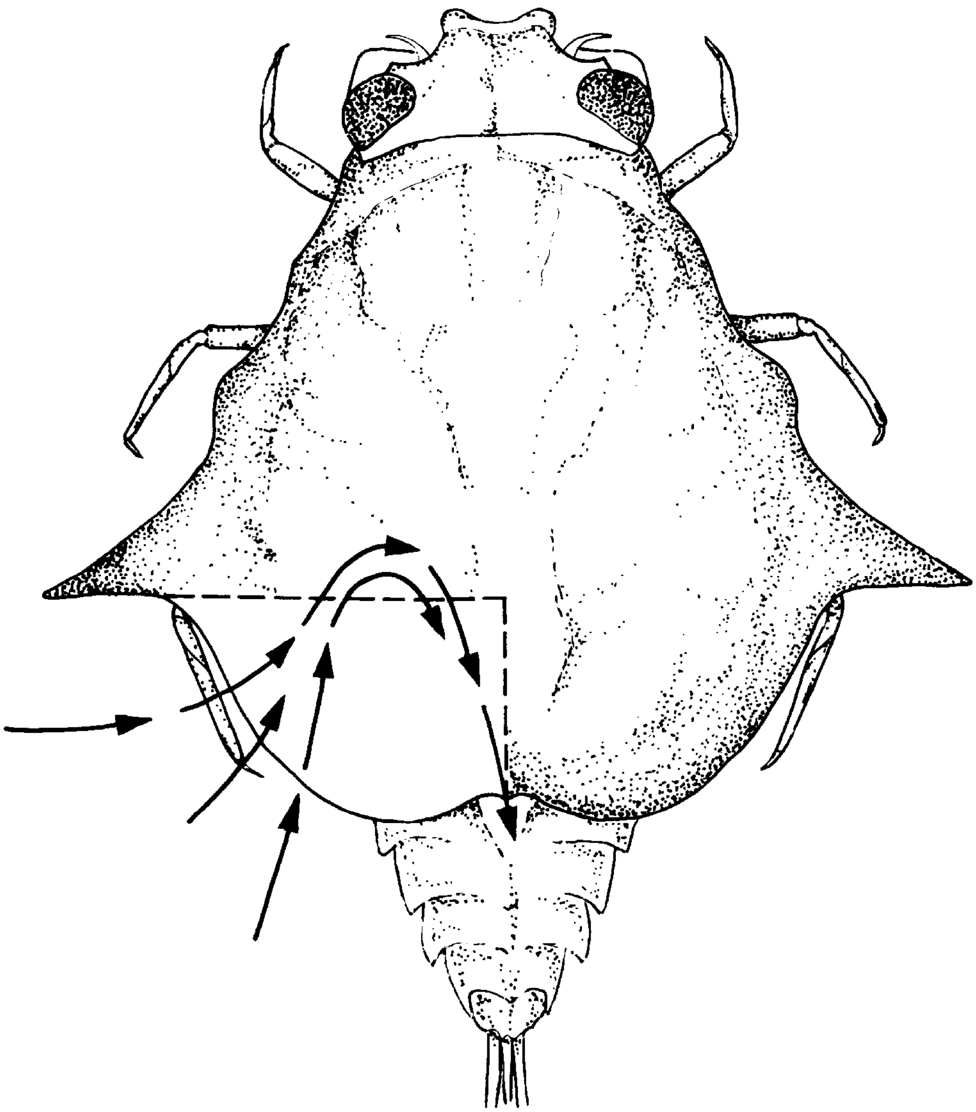

Fig. 1. Dorsal view of nymph of *Baetisca rogersi.* Arrows indicate the direction of water flow through the mesonotal chamber when a cut (indicated by the dotted line) is made to remove the posterior portion of the shield.

Materials and Methods

Nymphs of *B. rogersi* were collected by Dr. G. F. Edmunds, Jr. at Rocky Comfort Creek, Gadsden County, Florida on 30-III-1974 and returned alive to the University of Utah. The nymphs were placed in aerated aquaria with a variety of substrate types and allowed to acclimate for several days before observations were made.

Small observation aquaria were constructed by gluing microscope slides together with silicon rubber adhesive. Fine nylon net was placed on the bottom of the aquaria for a substrate; nymphs made minimal movement when the netting was available. All observations were made using a dissecting microscope.

Suspensions of elemental silicon powder (325 μm mesh and finer) were introduced into the water to facilitate observations. Other powdered materials which were tried included suspensions of lamp black, carmine, cellulose acetate and aluminium powder, but silicon powder was considered to be superior as it remained in suspension and distinct particles were easily visible.

Observations were first made with the mesonotal shield intact. The left posterior quarter of the shield was then removed, permitting gill movement to be observed in more detail.

Results

The gills of *B. rogersi* are paired structures inserted dorsolaterally on abdominal segments I-VI. All gills are membranous and tracheae are visible. The medial edges of gills I and III-V are dissected to varying degrees; the edges of gill VI are entire. Gill II is a large, platelike lamella with some sclerotization; the posterolateral area of this gill is somewhat thickened and folded, forming a scoop-like structure. The body is membranous in the area covered by the mesonotal shield and probably functions as a respiratory surface in addition to the gills; elsewhere, the bodies of the nymphs are highly sclerotized, reducing or preventing gas exchange.

At the start of a ventilation period, the nymph lowers the abdomen relative to the shield, permitting water to enter the mesonotal chamber near the posterolateral edge. Water exits along the median line between the sixth pair of gills which are small, delicate, and appear to remain passively shut. The nymphs can prevent the entry of water into the mesonotal chamber as the dorsolateral edges of the abdominal terga and the median abdominal hump can be held against the shield.

Figure 1 illustrates the path of water flow through the mesonotal chamber when the posterior corner of the shield is removed. The large platelike gill II appears to draw water into the chamber. The water moves towards the anterior of the chamber then flows medially and to the posterior to exit between the VIth pair of gills.

The large, filamentous gill on segment I overlies gill II and apparently has no role in the active propulsion of water through the chamber; it moves in synchrony with gill II. Gills III-V overlap and beat slightly out of synchrony, assisting in directing the water through the mesonotal chamber. Occasionally there is a slight twitch of the gills after the large gill beats, as if the gills are readjusting their position with respect to each other. There is a median furrow between the gills on segments III-Vwhich is covered by gill II; these gills are raised above the abdomen, forming a distinct space or area through which water flows.

Removal of the posterior corner of the shield does not hamper gill movement. Water flows into the gill area in approximately the same region as observed with the shield intact and flows out the posterior median channel between gills VI. However, if a larger portion of the shield is removed (anterior to the lateral spine), the flow of water over the gills is seriously affected; the area between the gills and the abdomen collapses, preventing adequate water flow.

In the region where water is drawn into the mesonotal chamber, there is a sparse row of hairs on the edge of the mesonotal shield. If the shield is touched lightly with a probe or the animal is disturbed in some manner (e.g., a suspension of fine particles injected over the nymph), the abdomen elevates to fit tightly against the shield. This presumably protects the gills within the chamber from sand or other particulate matter that may either physically damage the gills or interfere with their respiratory function.

Discussion

The beating of the gills in many mayfly nymphs produces a flow of water over and around the body (Eastham 1939, Eriksen & Moeur 1990, Wingfield 1939). The large mesonotal shield of *Baetisca* nymphs forms a chamber within which the gills lie; ventilatory currents of water, produced by the beating of gill II, carry fresh oxygenated water to the respiratory surfaces within the chamber. As water enters the chamber by the beating of gill II, water is expelled through the median excurrent channel formed by the gills on abdominal segment VI. My study provides further information on the movement of the water within the chamber formed by the mesonotal chamber and is in agreement with studies by Pescador & Peters (1974) and Berner (1950).

To function as gas exchange units, gills need to be kept clean of dirt, sand or other material (Eastham 1939, Needham et al. 1935). The habitats of nymphs of *Baetisca* vary, depending both on species and the maturity of the nymphs. Some nymphs may rest on sand or pebbly riffles in protected areas; others partially bury themselves in silt and sand (Edmunds et al. 1976). In any of these habitats, exposure to silt and other substances which interfere with the respiratory function of the gills may be encountered. The mesonotal chamber thus functions to protect the gills from both physical damage and from becoming clogged with particulate matter.

Morgan & Grierson (1932), Wingfield (1939), Eriksen (1963) and Eriksen & Moeur (1990) have shown that the general body surface of mayfly nymphs may be important in respiration; however, its importance is greatly reduced when the body is highly sclerotized as in nymphs of *Baetisca*. The highly dissected form of gills I and III-V and the extensive tracheation increases the surface area available for respiratory exchange. The hairs on the posterior edge of the mesonotal shield may have a sensory function similar to the hairs found on the gill opercula of *Caenis horaria* nymphs (Eastham 1936); Eastham determined that these hairs were able to detect potentially damaging substances, such as particulate matter in the water. The sparse distribution of these hairs on the mesonotal shield of *Baetisca* nymphs would not allow them to sieve particles from entering the chamber; however, when fine particles are introduced to the water around the shield, the abdomen is raised, preventing their entry.

Nymphs of *Baetisca* crawl up to 1 m from the water to emerge as subimagos (Edmunds & McCafferty 1988); the length of time for emergence ranges from 4 to 10 minutes in the laboratory and 5 to 7 minutes in the field (Pescador & Peters 1974). The mesonotal shield would assist in conserving moisture within the gill chamber during this period and may indirectly facilitate successful emergence by preventing desiccation.

Nymphs of *Baetisca* are difficult to detect on sandy or rocky substrate due to their coloration (dark and often mottled) and because the spines and other protuberances found on the shield and body help to break up the nymphal outline. Edmunds (1977) noted that *B. lacustris* McDunnough (= *B. bajkovi* Neave) nymphs in nature strongly resemble the pebbles among which they live. Pescador & Peters (1974) also suggested that the spines and other dorsal elevations may function to decrease current resistance in the nymphs.

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REFERENCES CITED

BERNER, L. 1950. The mayflies of Florida, University of Florida Press, Gainesville, 267p.

EASTHAM, L. E. S. 1936. The sensillae and related structures on the gills of nymphs of the genus *Caenis* (Ephemeroptera). Trans. R. Entomol. Soc. London. 85: 401-414.

EASTHAM, L. E. S. 1939. Gill movements of nymphal *Ephemera danica* (Ephemeroptera) and the currents produced by them in water. J. Exp. Biol. 16: 18-33.

EDMUNDS, G. F., JR. 1977. *Baetisca bajkovi* in Wyoming (Ephemeroptera: Baetiscidae). Pan-Pacif. Entomol. 53: 222.

EDMUNDS, G. F., JR., S. L. JENSEN, AND L. BERNER. 1976. The mayflies of North and Central America. Univ. Minnesota Press, Minneapolis, 330p.

EDMUNDS, G. F., JR., AND W. P. MCCAFFERTY. 1988. The mayfly subimago. Annu. Rev. Entomol. 33: 509-29.

ERIKSEN, C. H. 1963. Respiratory regulation in *Ephemera simulans* Walker and *Hexagenia limbata* (Serville) (Ephemeroptera). J. Exp. Biol. 40: 455-467.

ERIKSEN, C. H., AND J. E. MOEUR. 1990. Respiratory functions of motile tracheal gills in Ephemeroptera nymphs, as exemplified by *Siphlonurus occidentalis* Eaton, pp. 109-118 *in* I. C. Campbell, [ed.], Mayflies and Stoneflies, Kluwer Academic Publ., Netherlands.

MORGAN, A. H., AND M. C. GRIERSON. 1932. The functions of the gills in burrowing mayflies (*Hexagenia recurvata*). Physiol. Zool. 5: 230-245.

NEEDHAM, J. G., J. R. TRAVER, AND Y. HSU. 1935. The biology of mayflies with a systematic account of North American species. Comstock Publ. Co., Ithaca, N.Y., 759p.

PESCADOR, M. L., AND W. L. PETERS. 1974. The life history and ecology of *Baetisca rogersi* Berner (Ephemeroptera: Baetiscidae). Bull. Florida St. Mus., Biol. Sci. 17: 151-209.

WINGFIELD, C. A. 1939. The function of the gills of mayfly nymphs from different habitats. J. Exp. Biol. 16: 363-373.