ECOLOGICAL LIFE HISTORY OF *BAETISCA CAROLINA* TRAVER IN PANTHER CREEK, NICHOLAS COUNTY, WEST VIRGINIA (EPHEMEROPTERA: BAETISCIDAE)

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The main objective of this study was to elucidate the ecological life history of the mayfly *Baetisca carolina* Traver in Panther Creek, Nicholas Co., West Virginia. Additionally, multivariate discriminate analysis was used to separate *B. carolina* from the closely related *B. berneri.* Other authors, including Berner (1955, 1959), Pescador and Peters (1971, 1974), Lehmkuhl (1972), Chaffee and Tarter (1979), Morris et al. (1980) and Berner and Pescador (1980), have reported ecological studies on *Baetisca* species. Only a few investigators, including Smith (1935) and Traver (1931, 1937), have noted ecological information on *B. carolina.* Pettry and Tarter (1983) reported a relationship between body size and body coloration in *B. carolina* nymphs.

Taxonomy and Distribution

The endemic family Baetiscidae is monotypic, containing only the genus *Baetisca* (Walsh 1862). Traver (1931) described the nymph, subimago and imago of *B. carolina.* Traver (1937) described *B. thomsenae* which Berner later synonymized with *B. carolina.* Pescador and Berner (1981) proposed that *B. carolina* is part of a group that was pushed into or trapped in the ice-free streams of the Appalachians (Georgia, South Carolina, North Carolina, Tennessee and Virginia) during the Pleistocene glaciation and has remained in the cool mountain streams until the present time. Needham et al. (1935) reported *B. carolina* nymphs from the Morgantown, West Virginia vicinity.

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Materials and Methods

The study area is Panther Creek of the Gauley River in Nicholas County, West Virginia. The total length is 16 km and the area of the drainage basin is 42.2 km^2 (Reger, 1921). The study site is located along Route 39 at the community of Nettie, 22.7 m from the junction of Route 19 at Summersville, West Virginia. The stream width averages 9 m and the water depth averages 46 cm. Substrate consists of sand, gravel, and small rocks. The most dominant species of the riparian forest are Hemlock, *Tsuga canadensis* (L.) Carr, and Rhododendron, *Rhododendron maximum* L.

Monthly samples of nymphs were collected from October 1981 to September 1982. The substrate was disturbed by kicking the rocks and a hand dredge (mesh size, 0.75 mm^2) was held downstream to collect the nymphs. The nymphs were preserved in 70 percent ethanol.

The water chemistry parameters were measured monthly with a Hach kit, Model AL-36-WR. Dissolved oxygen (mg/l), carbon dioxide (mg/l), alkalinity (mg/l $CaCO_3$), total hardness (mg/l $CaCO_3$), and pH were recorded throughout the study period. Water temperature was recorded monthly with a Taylor thermometer placed about 5 cm below the surface of the water.

Nymphal size classes were determined by length-frequency histograms arranged in 1 mm length groups. Body length from the tip of head (excluding genal spines) to the base of the caudal filament was measured to the nearest 0.1 mm using an ocular micrometer. Males, females, and immatures were combined for the histogram analysis. Head capsule width, measured to the nearest 0.01 mm with an ocular micrometer, was used as an index of growth. Monthly differences in nymphal head capsule widths were used to calculate the mean, range and two standard errors of the mean.

Five nymphs were randomly selected for each month for foregut analysis. The head was severed with microdissecting scissors and the thoracic shield was removed, thus exposing the foregut. The foregut was removed and its contents emptied onto a glass slide with an iodine solution as the mounting medium. The contents were examined under a Bausch and Lomb (430×) dissecting microscope containing a Whipple ocular grid. Five grids were randomly selected for examination from each nymph. The percentage composition for each food category (filamentous algae, plant detritus, mineral detritus, diatoms) was determined by figuring the percentage of small grid squares within each field that contained each of the different food categories.

Multivariate discriminant analysis, using the computer program BMDP7M (Dixon, 1981), was used to separate *B. carolina* from the closely related *B. berneri.* Thirteen morphological characters (shield length and width, head width, length of caudal filament, body length, prothoracic leg and claw length, mesothoracic leg tibia and femur length, mesothoracic leg tarsus and claw length, width of abdominal segment 10, labrum width) were measured on all nymphs (15) of *B. berneri* (holotype locality, Laurel Fork, West Virginia) and from five different geographical populations (Georgia, North Carolina, Tennessee, Virginia, and West Virginia - Panther Creek) of *B. carolina* nymphs (85). Two colormorphs from Panther Creek were included in the analysis. Males and females were grouped together in the analysis. Because of size variation within and among populations, regression analyses were applied to all measurements to remove the linearly related effects of size. Head width was used as the independent variable for regression of the other variables. The SAS General Linear Models procedure (Barr et al., 1976) produced residual values for each character; these values were then used as "size-free" variables. In the final analysis, the computer program (BMDP7M) generates canonical variates with maximum between group variance relative to their within group variance. The canonical variate means are plotted on the first two canonical axes, and analysis of variance describes significant differences between groups ($P < 0.01$). Using canonical functions, the posterior probability of each nymph belonging to its respective population is computed and classified accordingly.

In order to determine the fecundity of *B. carolina,* direct egg counts were made on adults. The dorsal body cavity of ten females (four imagos and six subimagos) was opened longitudinally with microdissecting scissors. The eggs were carefully removed, placed in a Petri dish, and counted under a Bausch and Lomb dissecting microscope. The regression of fecundity on body length was calculated and a coefficient of correlation was determined. The diameter of 50 eggs per female was measured with an ocular micrometer in a dissecting microscope to the nearest 0.01 mm.

Results and Discussion

Water Quality. Dissolved oxygen concentration ranged from 8 (May and July) to 13 mg/l (December); the mean was 11.0 mg/l. The mean hydrogen ion concentration (pH) was 8.5; a range of 7.0 (June) to 10.0 (August). The carbon dioxide level was 0.0 mg/l during all months except August (15.0). Total hardness ranged from 34.2 (December–April) to 102.6 mg/l (August); the mean was 48.5 mg/l. The mean annual water temperature during the study period was 9.8 C; the range was −1 (December) to 19.0 C (May, June, September).

Nymphal Stage

Foregut Analysis. The nymphs are detritivorous with 68.5 percent of the diet composed of plant detritus. Plant detritus was greatest during the months of December through May. Mineral detritus, probably ingested accidentally, was regularly observed in the foregut every month ($\bar{X}$ = 21.7%). Diatoms, usually *Cymbella* and *Navicula,* comprised 8.9% of the diet. They increased during the months of July through October. Filamentous algae, mainly *Oedogonium* and *Oscillatoria,* made up about one percent of the diet.

Chaffee and Tarter (1979) noted that the nymphs of *B. bajkovi* (= *lacustris*) are detritivorous with 65.3 percent of the diet composed of plant and leaf detritus. The nymphs of *B. berneri* are detritivorous with 74.5 percent of the diet made up of organic and mineral detritus (Morris et al., 1980).

Development. Monthly length-frequency histograms indicated a one year (univoltine) life cycle (Figure 1). The smallest nymph (1.3 mm) was collected in September and the largest nymph (10.9 mm) was collected in late April.

Univoltine life cycles were reported for *B. rogersi* (Pescador and Peters, 1974), *B. berneri* (Morris et al., 1980) and *B. bajkovi* (= *lacustris*) (Chaffee and Tarter, 1980).

The monthly progression of mean head widths for male and female nymphs is illustrated in Figure 2. Male nymphs showed the greatest growth in April (28%) and July (27%). Female nymphs showed the greatest growth in April (16%) and July (34%). Little or

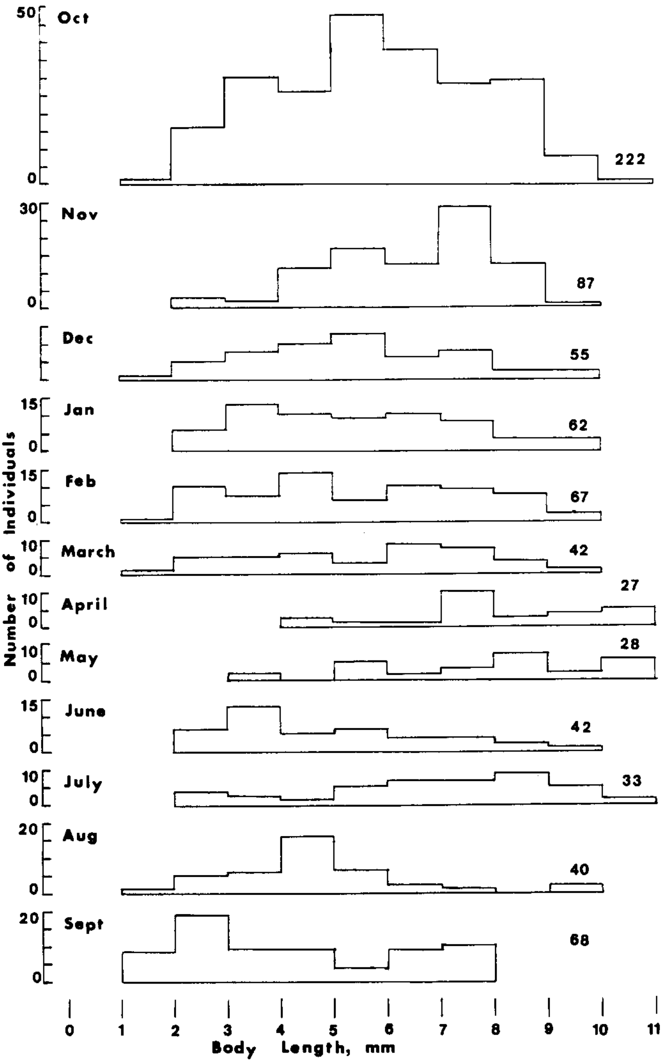

Figure 1. Length-frequency histograms showing the monthly distributions of *Baetisca carolina* nymphs from Panther Creek, Nicholas County, West Virginia. The number of individuals collected is indicated at the right.

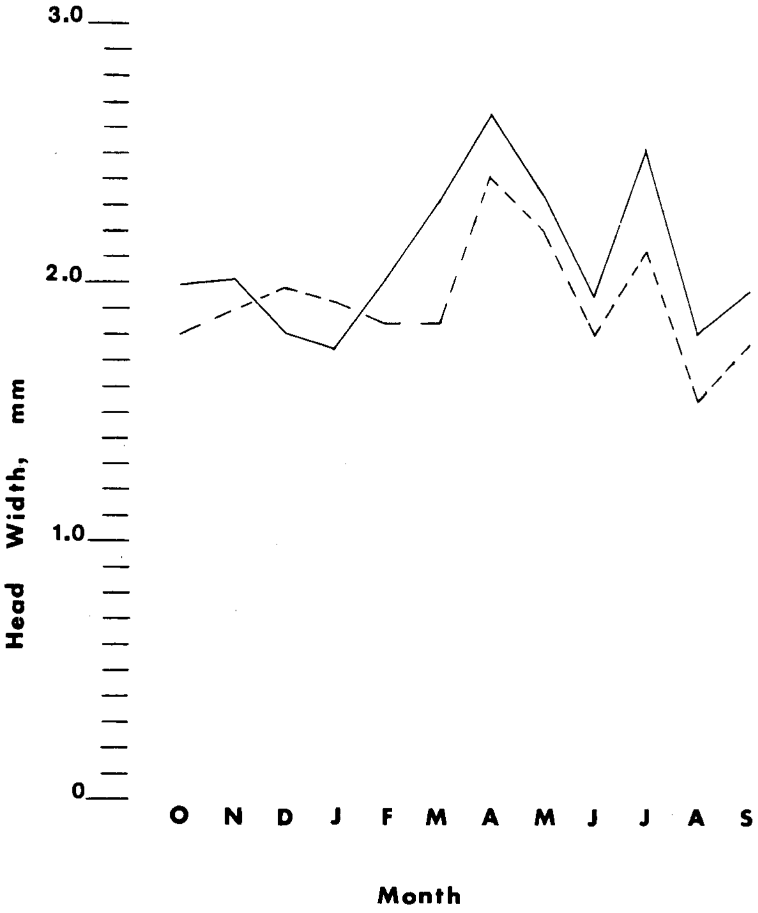

Figure 2. Growth of *Baetisca carolina* nymphs based on mean monthly head widths. Solid line represents female growth; broken line represents male growth.

no growth occurred in the winter months, but as the water temperature began to rise, growth began to occur. Nymphs showed the greatest head width in April, while they exhibited a decline in mean head width in May and June. This decline is due to the emergence of the larger nymphs. The large growth rate in July is probably due to nymphs growing in preparation for a second emergence in August. These data, along with data from nymphal exuviae and length-frequency histograms, support the viewpoint of bimodal emergence and a univoltine life cycle.

The population range diagram shows the wide range of head widths that occurred each month (Figure 3). Immature nymphs that were too small to be sexed are not represented in the diagrams. The largest head width for males was 2.9 mm, and for females 3.4 mm; both occurred in April. Size superiority exhibited by females is shown in Figures 2 and 3.

Morphological Analysis. Results from the discriminant analysis of all *B. carolina* popultions are presented in Figure 4. The first two canonical axes were responsible for 83.2 and 8.5 percent of the total dispersion, respectively. One hundred percent dispersion was obtained when four axes were utilized. The most influential characters providing separation on the first axis, in order of increasing weight, were: mesothoracic leg femur length; body length; shield width; and mesothoracic leg tarsus length. Overlap of canonical coordinates for individuals of different geographical populations indicates that substantial morphological variation exists within populations. Canonical coordinates for populations on the first (horizontal) axis generally followed a north-south geographical cline.

The light and dark colormorphs from Panther Creek showed extensive overlap, and a relatively high percentage of individuals were classified incorrectly between these two groups relative to the other groups in this analysis. This further indicated that one species of *Baetisca* nymphs exists in Panther Creek, rather than two species as was assumed at the onset of this study.

Baetisca berneri nymphs from the holotype locality showed considerable morphological similarity to the Virginia and Tennessee populations of *B. carolina.*

Pescador and Berner (1981) noted morphological variation among geographical populations of *B. carolina* nymphs. They reported that nymphs from the northern extension of their range have a broader mesonotal shield and shorter lateral spines than nymphs from the southern extension of their range. The nymphs from Panther Creek exhibited a broad mesonotal shield and short lateral spines. Additionally, it was observed in this study that nymphs from the northern extension of their range exhibited shorter genal spines on the head.

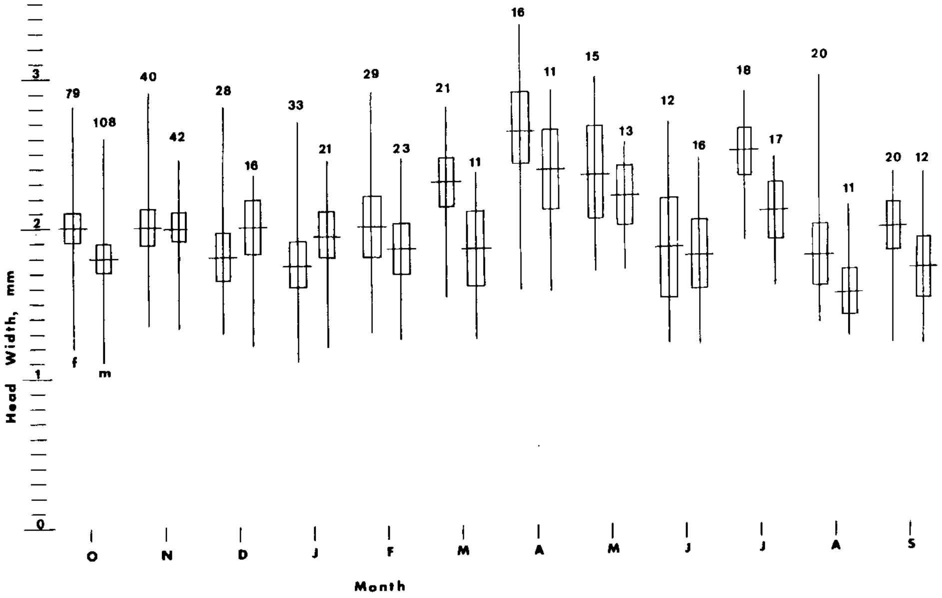

Figure 3. Population range diagram showing monthly head width variations of *Baetisca carolina* nymphs from Panther Creek, Nicholas County, West Virginia. Vertical lines = range, horizontal lines = mean, open rectangle = two standard errors of the mean, f = female, and m = male.

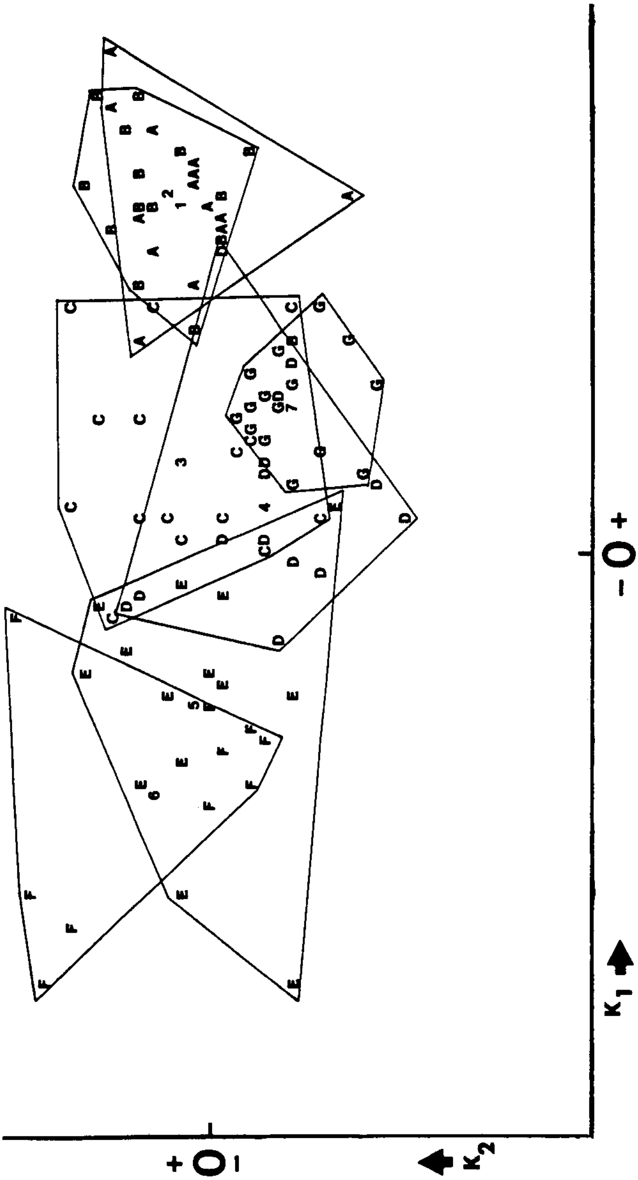

Figure 4. Variates for nymphs of *Baetisca carolina* and *B. berneri* plotted on the first and second canonical axes. Individual nymphs are represented by letters, and numbers represent canonical variate means for the population. A, light colormorph of *B. carolina* from Panther Creek; B, dark colormorph of *B. carolina* from Panther Creek; C, *B. carolina* from Virginia; D, *B. carolina* nymphs from Tennessee; E, *B. carolina* nymphs from North Carolina; F, *B. carolina* nymphs from Georgia; G, *B. berneri* nymphs from the holotype locality, Laurel Fork, Mingo County, West Virginia.

Nymphal Coloration. Considerable inconsistency was noted in the regularity of the coloration exhibited by *B. carolina* nymphs during the monthly collections (Pettry and Tarter, 1983). During fall and winter months, the majority of the nymphs exhibited a dark body coloration, with dark pigmentation on the legs and on the ventral surface of the head, thorax and abdomen. In spring and summer, as the nymphs grew and approached the emergence period, the dark pigmentation diminished among most of the nymphs. These monthly increases and decreases in percentages of light individuals corresponded to the monthly increases and decreases in the growth pattern shown by nymphs, indicating that body coloration is associated with body size ($r = 0.87$).

Traver (1931) noted considerable color variation in *B. carolina* nymphs in the original description of the species. Also, Traver (1937) noted color variation in *B. thomsenae* (= *carolina*) nymphs. This study confirms Traver's original observations, and additionally indicates that two colormorphs exist in Panther Creek.

Adult Stage

Field Studies. Nymphs with developing wing pads were first observed in Panther Creek on April 23. Emergence in the field began between May 15 and 19 and continued through the end of August.

Traver (1931) reported emergence of *B. carolina* in April and May. Traver (1937) observed *B. thomsenae* (= *carolina*) in May and June. The emergence period data reported for other *Baetisca* species are as follows: Pescador and Peters (1974), *B. rogersi,* April through early July; Morris et al. (1978), *B. berneri,* May and early June; Chaffee and Tarter (1979), *B. bajkovi* (= *lacustris*), May.

Exuviae were collected during the emergence period to determine the yearly pattern of emergence. These data indicated a bimodal emergence pattern. The primary peak occurred in May when emergence began, with the other peak in August near the end of the emergence period. The data for early June may not correctly represent the actual emergence pattern. Heavy rains were recorded during this time, 3.85 inches (97.8 mm) fell during the first week of June and undoubtedly washed away nymphal exuviae. The water level of Panther Creek rose four feet during this time. The effect of high water on emergence is unknown; however, emergence continued

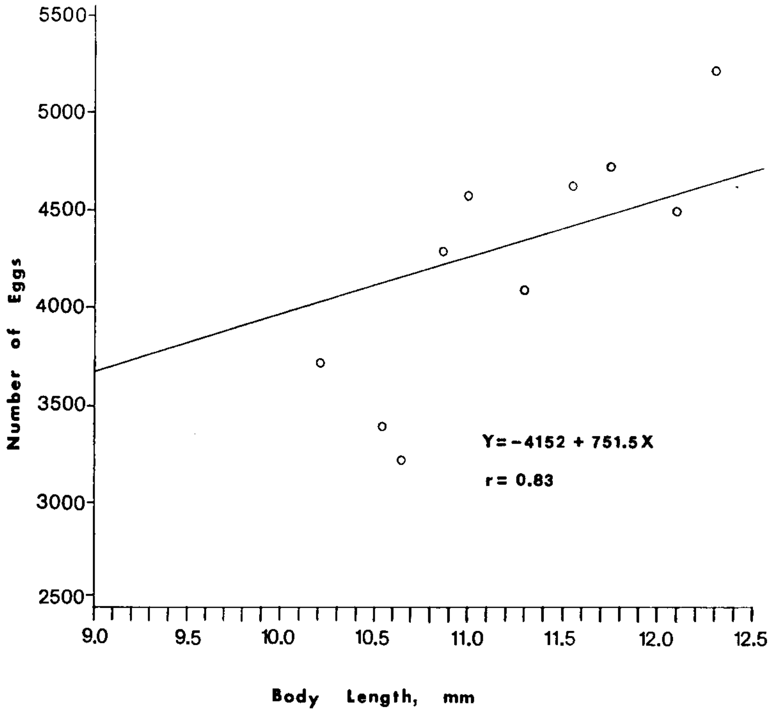

Figure 5. Fecundity-length regression analysis and the coefficient of correlation for adult females of *Baetisca carolina,* Panther Creek, Nicholas County, West Virginia.

since small numbers of exuviae were found. Even though these data can be adversely affected by environmental conditions such as rain, the general emergence pattern is supported by growth data of the nymphs. The two peak emergence periods corresponded to the two growth periods exhibited by the nymphal population (Figure 2).

Rearing and Emergence. Last instar *B. carolina* nymphs were reared in the laboratory beginning in late April. Only one subimago, a female, emerged in the laboratory. This occurred before 1:00 p.m. on May 6, and the subimago died before transforming into an imago.

Subimagos collected in the field successfully completed the transformation to the imaginal stage in the laboratory. Duration of the subimaginal stage of *B. carolina* was recorded for two individuals at laboratory temperatures. A female subimago transformed in 24 hours and 27 minutes, while a male subimago transformed in 20 hours and 29 minutes. The male imago lived 48 hours.

Subimaginal transformation data for other species of the genus *Baetisca* have been reported by other authors. Traver (1931) reported that the subimago stage of *B. carolina* varied between 21 and 24 hours under warm temperatures, while enduring up to 50 hours during cold weather. Berner (1955) observed *B. escambiensis* subimagos transforming to imagos in 40 to 44 hours. Pescador and Peters (1974) reported that the duration of the subimaginal stage of *B. rogersi* ranged from 12 to 30 hours, averaging 21 hours and 21 minutes. Morris et al. (1980) observed that the duration of the subimaginal stage of *B. berneri* was approximately 24 hours. Chaffee and Tarter (1979) reported that *B. bajkovi* (= *lacustris*) subimagos transformed into imagos 13 to 25 hours later.

Fecundity. Direct egg counts for ten *B. carolina* adults ranged from 3271 to 5274 per individual, averaging 4280. A correlation coefficient between fecundity and body size was determined to be 0.83 (Figure 5). Pescador and Peters (1974) reported egg counts from *B. rogersi* adults ranged from 1500 to 2727 per individual, averaging 2168. Morris et al. (1980) reported egg counts from *B. berneri* adults ranged from 1001 to 2375 per individual, averaging 1899. Chaffee and Tarter (1979) reported egg counts from *B. bajkovi* (= *lacustris*) adults ranged from 1508 to 3158 per individual, averaging 2361.

Egg Size. The eggs of *B. carolina* have an average diameter of 0.17 mm. Individual eggs ranged from 0.14 to 0.21 mm. Egg diameter measurements from SEM photomicrographs showed ranges from 130 to 160 microns, averaging approximately 145 microns.

Smith (1935) reported the egg diameter of *B. carolina* and *B. obesa* to be 0.18 mm. Pescador and Peters (1974) reported that newly laid eggs of *B. rogersi* had a diameter of 0.1 to 0.2 mm, while mature eggs had a diameter of 0.2 to 0.3 mm. Morris et al. (1980) reported that eggs of *B. berneri* had an average diameter of 0.18 mm. Chaffee and Tarter (1979) reported that eggs of *B. bajkovi* (= *lacustris*) had average measurements of 0.15 $\times$ 0.19 mm.

Summary

The ecological life history of the mayfly *Baetisca carolina* Traver was studied in Panther Creek, Nicholas County, West Virginia, from October 1981 to September 1982. Nymphs were primarily collected from a sand and small stone substrate. Length-frequency distributions indicate a one year (univoltine) life cycle. Male and female nymphs exhibited the greatest growth in April and July. Females exhibit a definite size superiority. Monthly foregut analysis indicates that nymphs are primarily detritivouous, with other components of the diet including diatoms and filamentous algae. Two colormorphs, light and dark, are present in the population. As nymphal size increases, a greater percentage of the population exhibits light body coloration. Multivariate discriminant analysis was used to separate *B. carolina* from the closely related *B. berneri*. Subimagos emerge in the field from mid-May through the end of August. A bimodal pattern of emergence was observed. Imagos emerged approximately 24 hours later. Direct egg counts ranged from 3271 to 5274 per female; the average was 4280. The correlation coefficient between fecundity and body size was 0.83.

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