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THE LIFE HISTORY AND ECOLOGY OF *BAETISCA ROGERSI* BERNER (EPHEMEROPTERA: BAETISCIDAE)

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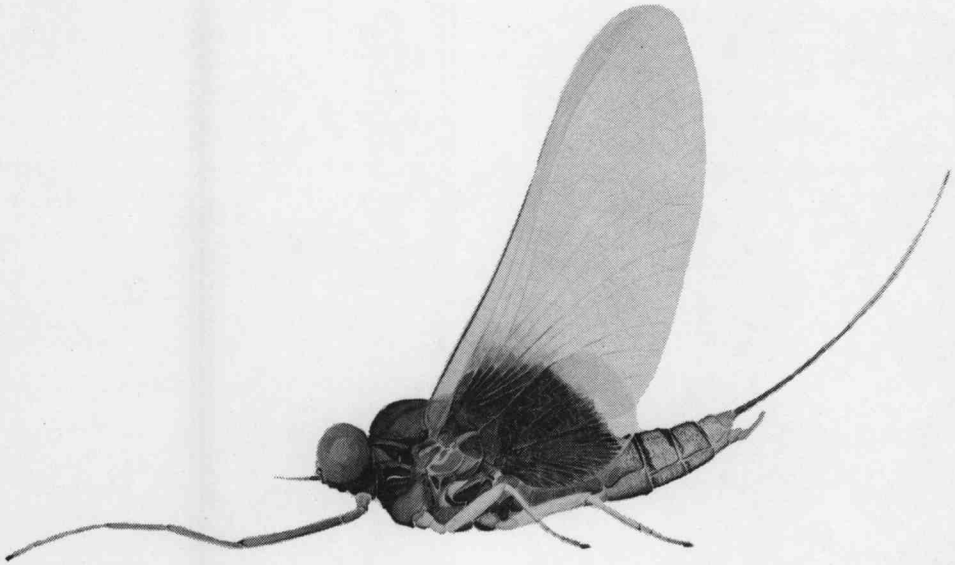

FIGURE 1.—LATERAL VIEW OF MALE IMAGO OF *Baetisca Rogersi*.

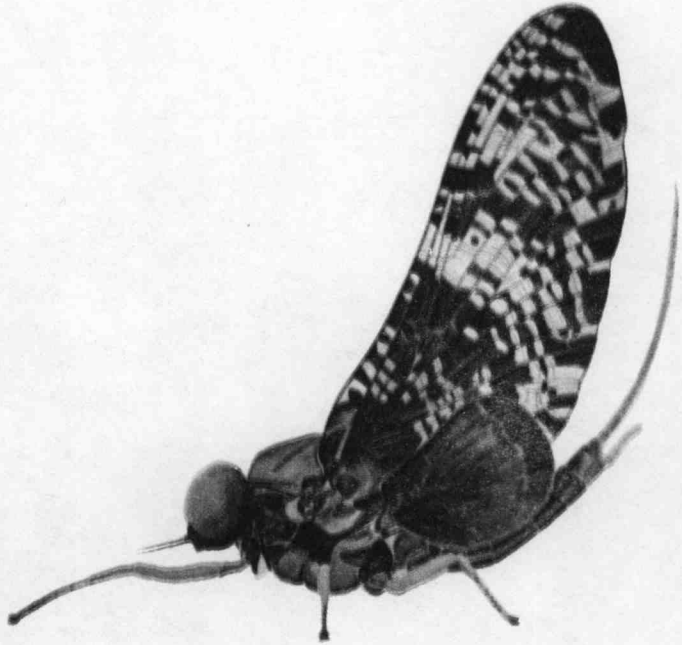

FIGURE 2.—LATERAL VIEW OF MALE SUBIMAGO OF *B. Rogersi*.

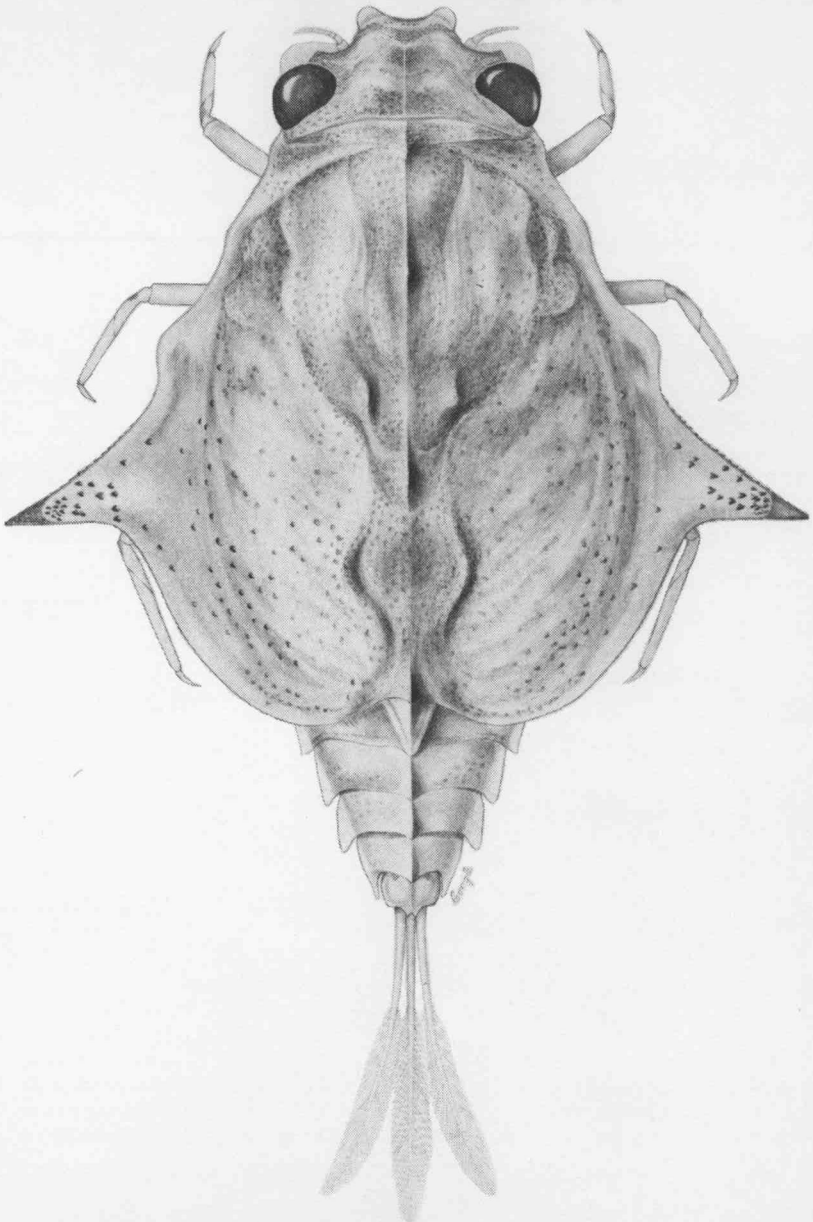

FIGURE 3.—Dorsal view of mature female nymph of *B. rogersi* [after Berner (1950)].

THE LIFE HISTORY AND ECOLOGY OF *BAETISCA ROGERSI* BERNER (EPHEMEROPTERA: BAETISCIDAE)[1]

MANUEL L. PESCADOR AND WILLIAM L. PETERS[2]

SYNOPSIS: This report describes the life history and ecology of *Baetisca rogersi* Berner (Ephemeroptera: Baetiscidae) in northwestern Florida. It includes a description of external morphology, duration, and behavior of the different life history stages and also considers seasonal distribution, growth, and emergence. It discusses factors influencing ecology of the species, particularly those affecting growth, development, and seasonal distribution, and identifies associated arthropods.

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[2] Manuel L. Pescador, a graduate student in the Department of Biological Science, Florida State University, Tallahassee, under a cooperative agreement between Florida State University and Florida A & M University, submitted a portion of this paper in partial fulfillment of the requirements for the Master of Science degree, Department of Biological Science, Florida State University.

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INTRODUCTION

The life history and ecology of most mayfly (Ephemeroptera) species in North America are unknown. Recently ecological studies of aquatic insects have attracted the attention of many biologists, especially in North America, Europe, and Africa because of these insects' importance in freshwater communities, their role in fisheries, and their sensitivity to pollution. Mayflies are an excellent tool for studying environmental relationships and the importance of a favorable environment for all forms of aquatic life. Knowledge of their ecology and life history is essential in understanding the biological structure of freshwater streams and lakes.

To help enlarge our knowledge of mayfly species in the southeastern United States, investigations of their ecology have been initiated at Florida A & M University. This study, which is a part of the main research project at Florida A & M University, investigates ecology, life history, seasonal distribution, and habitat of *Baetisca rogersi* Berner, and lays a foundation for continued work.

B. rogersi is common in northern Florida, southern Alabama, Georgia, and South Carolina. Nymphs live in shallow rocky or sandy streams with a moderately slow to fast current. Berner (1950) summarized his observations on ecology, seasonal distribution, habits, and life history of the species. He briefly described the general habitat and discussed the species' distribution.

The objectives of this study were to determine: (1) stages in the life history, (2) ecology of the life stages, (3) habits of both nymphs and imagos under field and laboratory conditions, and (4) seasonal distribution of *B. rogersi*.

ACKNOWLEDGMENTS

We extend our sincere appreciation and thanks to the many persons who have given valuable aid, assistance, and encouragement during the course of this investigation.

We especially thank E. C. Beck, Bureau of Entomology, Florida Division of Health, Jacksonville; W. M. Beck, Jr., Florida A & M University; E. L. Bousfield, National Museum of Canada, Ottawa; G. W. Byers, University of Kansas, Lawrence; O. S. Flint, Jr., U. S. National Museum; J. J. Franklin, Florida A & M University; H. H. Hobbs, U. S. National Museum; S. G. Jewett, Jr., Portland, Oregon; R. Ocampo-Paus, Florida State University; P. J. Spangler, U. S. National Museum; V. Sullivan, Iowa State University, Ames; and M. J. Westfall, Jr., University of Florida, Gainesville, for identification of specimens.

We thank Lewis Berner, University of Florida, for his encouragement during the study and for permitting use of the full nymph illustration.

We thank E. T. Hall, State Water Quality Control Board, Atlanta, for specimens of *B. rogersi* used in compiling distribution records, and Janice G. Peters, Florida A & M University, for preparation of the illustrations under our supervision. We gratefully acknowledge Jerome Jones, Philip T. P. Tsui, and Paul H. Carlson for their valuable help and encouragement during the course of the study. We wish to thank Charles E. Rockwood, Florida State University, for permission to conduct a portion of this study on his property at Bear Creek, Gadsden County, Florida. We offer our deep appreciation to Michael Hubbard, Florida State University for help in conducting the behavior study. We also thank D. R. Davis, North Florida Experiment Station, Quincy, for permitting use of the 1968-1969 data on air temperature. To the many others who contributed to this study we offer our sincere appreciation.

METHODS

We used many methods to collect and rear specimens, but give only successful methods here as an aid to future studies. All eggs used in this study came directly from female subimagos and imagos. Female

gonads dissected with jeweler's forceps were placed in small plastic petri dishes, 60 × 15 mm, half filled with distilled water. Eggs extracted from each female imago were counted under a dissecting microscope with an ocular grid to determine reproductive potential. To determine whether *B. rogersi* exhibits parthenogenesis, we took eggs from female subimagos and imagos reared individually in separate aquaria, and incubated the eggs in distilled water to avoid possible sperm contamination.

Eggs were fertilized by artificial insemination, achieved by crushing the reproductive organs of a male imago and a female imago in a depression slide filled with distilled water or Hobson's Ringer Solution as Barnes (1937) suggested. After 3 hours in the insemination medium the eggs were transferred into small, plastic petri dishes containing either steam or distilled water. They were then incubaetd at room temperatures of 20° C to 32.2° C. Water was changed every 2 days and water temperatures recorded daily. Nymphs hatched from eggs were reared through the first three instars in the laboratory, but all died before achieving the fourth instar. Field collections were necessary to supplement the life history.

We made field collections of the first five instar nymphs using Anderson's (1959) modified flotation technique. We also collected young nymphs from fresh samples of bottom substrate brought in from the study area at weekly intervals for 3 months, September to November 1968. Although laborious, this technique allowed us to collect live small nymphs free from injuries or mutilation. Most fourth to sixth instar nymphs were obtained this way. The seventh to twelfth instars were collected with a plastic handscreen throughout the study, December 1967 to July 1969.

We carried live nymphs to the laboratory in plastic buckets containing a small quantity of stream water with a dampened cloth in the bottom of the container. If no attachment surface is provided, the nymphs will cling to one another and injure themselves as they splash against the sides. Rocks or gravel are unsuitable for attachment because they tumble about and can damage the specimens. Wet moss can be substituted for cloth.

Early instar nymphs were reared in small plastic petri dishes of stream water with a thin layer of fine sand in the bottom for an attachment surface. Food (fresh, bottom substrate and living diatoms) and water were changed every 2 days. The water was aerated by the vibration of air pumps placed near the pans containing the petri dishes. These compressors were primarily used to aerate large aquaria, but their vibration alone agitated the water in the dishes enough to aerate it.

The seventh to last instar nymphs were reared in 2 gallon glass aquaria. Each aquarium contained 5 liters of stream water which was changed weekly. The water was treated with streptomycin sulfate USP (0.5 cc/3.5 l water) and was aerated and filtered by a single air-pump-operated filter. Each aquarium received additional aeration from two air stones connected to an air compressor. Three plastic screen rearing cages per aquarium confined and separated individual nymphs. Specimens intended for parthenogenetic tests were reared individually in different aquaria to avoid possible sperm contamination. All eggs and spermatozoa came from specimens reared this way. Plastic screen covers protected the rearing cages from dust and prevented the escape of emerging adults. A thin layer of sand and gravel was placed in the bottom of each cage and food was added every 2 days. Bottom substrate from the study areas composed of sand, gravel, detritus, water moss (*Leptodictyum riparium*), and filamentous algae (*Spirogyra* sp.) served as a food source.

Although we made weekly attempts to collect *B. rogersi* adults with field light traps from March to May 1968, we caught only two female subimagos. Both came to light on 28 April 1968 at 9:45 PM. Equipment used on different occasions included a gasoline 2-mantel pressure lantern, a 200-250 volt mercury vapor bulb powered by a 1-hp generator, and a battery operated 110 volt black light.

The following emergence season we used another method to collect adults in the field. The nymphs of *B. rogersi* climb onto fixed solid objects above water level to emerge. We captured newly emerged subimagos with insect nets as they rested before taking flight.

Nymphs intended for gut analyses were preserved in 10% formalin. The whole gut of five specimens of different sizes was dissected monthly and the contents extruded onto a slide with Turtox CMC-10-Non-Resinous Mountant. To determine the percentage composition of detritus, algae, and indigestible material, the slides were studied and counts were made on three nymphs per month using a method similar to that of Minshall (1967): the entire slide was scanned and five representative fields were counted, each representing one square of an ocular grid. Individual clumps of detritus, individual diatom frustules, individual mineral particles, recognizable filamentous algae, and arthropod remains were counted as separate items.

Nymphal habitat preferences were studied in the field and in two sets of laboratory experiments. Three trials were run in each experiment, using 36 × 12 × 2-inch galvenized iron tray filled with stream water and divided into three equal sections: A, B, and C (Fig. 4 A). The bottom of section A was covered with a mixture of sand, gravel, and

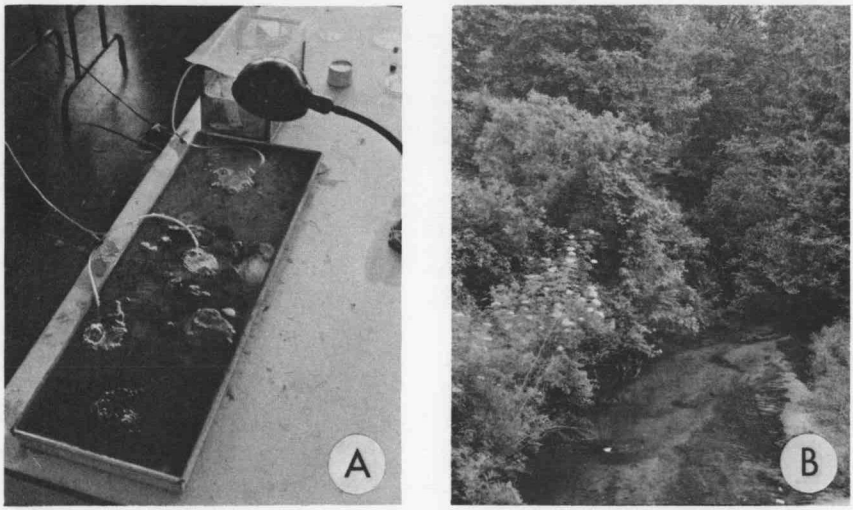

FIGURE 4.—A) Experimental laboratory equipment used to study habitat preference of nymphs. B) Collecting site at Bear Creek.

pebbles; section B with sand only; and section C with leaf litter. Each section was aerated by an air stone. Fifteen ninth to eleventh instar nymphs were introduced into the tray and data recorded after 12, 36, and 48 hours. In the first experiment, a high-intensity lamp lighted the entire tray. In the second experiment one section was exposed to a light source and the remaining sections covered. In trials I and II, section C was lighted for the first 12 hours while the remaining two sections were covered. Then section B was lighted while A and C were dark. Section A was lighted for the last 12 hours. In trial III, section A was lighted first, followed by B and C.

To study the dorsal light response, we placed 10 nymphs in a glass tube filled with stream water. In an otherwise dark room, a beam of light was projected into the tube and nymphal behavior was recorded.

To determine hourly adult emergence in nature, we regularly counted emerging subimagos on 23 tree stumps in Rocky Comfort Creek. After first removing exuviae from previous emergences, fresh exuviae were collected at one-hour intervals from 8:30 AM to 2:30 PM. The time required for subimaginal emergence was determined from the moment the nymphal thoracic notal shield began to split until the subimago emerged from the nymphal exuvia. Habits shown by the subimagos were noted.

Laboratory subimago data included hourly emergence, time required for subimaginal emergence, duration of the subimaginal stage, and time required for the subimaginal molt. Data on longevity or life span of

imagos included the time of molt and the time of death. Physical factors pertinent to subimaginal duration and imaginal longevity were recorded.

We conducted tests for dissolved oxygen, free carbon dioxide, and calcium carbonate to determine possible factors important in nymphal life cycle and distribution. We measured water temperatures 3 inches below the water surface with a pocket thermometer and determined water velocity by the cork flotation method. Water chemistry, pH, and water velocity were recorded at monthly intervals and water temperature at weekly intervals.

Description of the Study Areas

Field studies were conducted at Rocky Comfort Creek and Bear Creek in Gadsden County, Florida. Both streams are tributaries of the Ochlockonee River. The sites for all collections and field studies were: (1) TIN, R3W, S32, a small riffle portion of Rocky Comfort Creek, at bridge on a dirt road 6 miles south of State Highway 268; and (2) TIS, R3W, S30, a short sandy stretch of Bear Creek, at bridge on a dirt road 8 miles south of State Highway 268 and 1 mile north of State Highway 65C (Fig. 6 B).

Rocky Comfort Creek

Rocky Comfort Creek is a small spring-fed stream. It flows approximately 13.2 miles and averages about 33 feet wide. The substratum is mainly of a mixture of sand and clay except in the upper reaches where eroding limestones and riffles prevail. Much of the substratum supports no vegetation.

Along the banks of the creek are thick stands of trees and shrubs whose leaves are the stream's principal source of organic detritus. Among the higher plants are: *Sambucus canadensis* (common elder), *Itea virginica* (sweet spire), *Salix nigra* (black willow), *Carpinus caroliniana* (American hornbeam), *Fagus grandifolia* (American beech), *Pinus glabra* (spruce pine), *P. clausa* (sand pine), and *Quercus nigra* (water oak).

One permanent sampling station was in a riffle area 3.9 miles from the mouth of the stream (Fig. 5); it averaged 15 feet wide by 30 feet long. The basic substratum was rubble and gravel integrated with coarse sand in quieter water. Current velocity ranged from 0.9–1.3 feet per second. Maximuim depth was 2 feet, which dropped as low as 0.5 foot in summer. One-half of the sampling area received direct sunlight. Figure 7 gives seasonal variations in air and water temperatures.

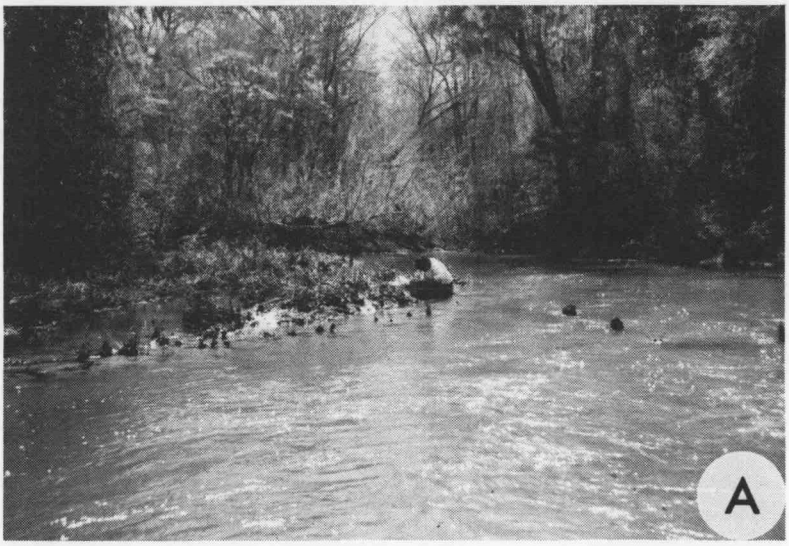

FIGURE 5.—A, B) Views of collecting station at Rocky Comfort Creek.

Water temperatures ranged from 5° C in January to 25° C in mid-summer. The stream was mildly acid to circumneutral (6.7-7.1 pH). Dissolved oxygen content ranged from 4.7 mg/1 to 7.6 mg/1 in winter,

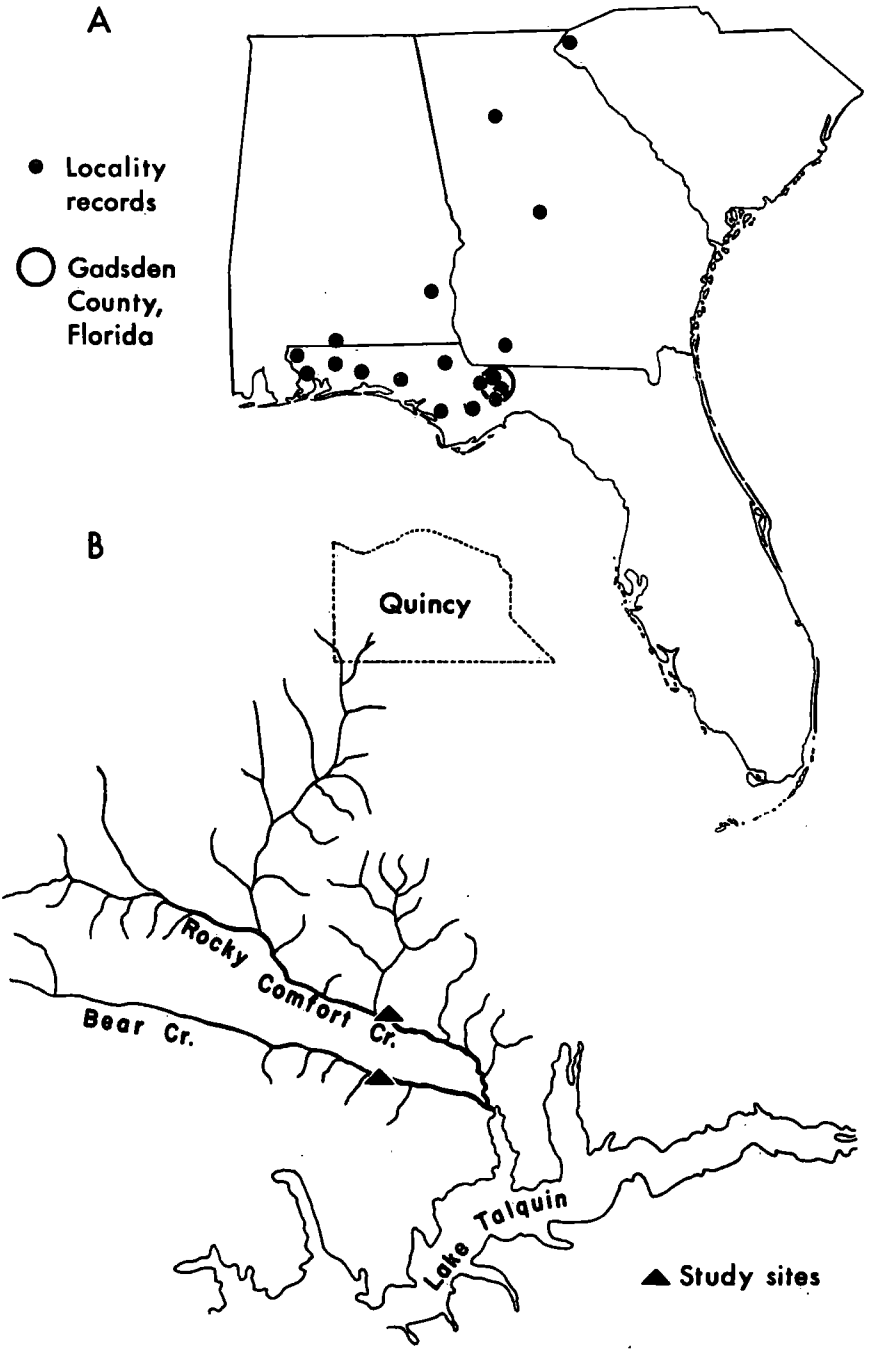

FIGURE 6.—A) Geographical distribution of *B. rogersi*. B) Map of Rocky Comfort and Bear Creeks showing study areas.

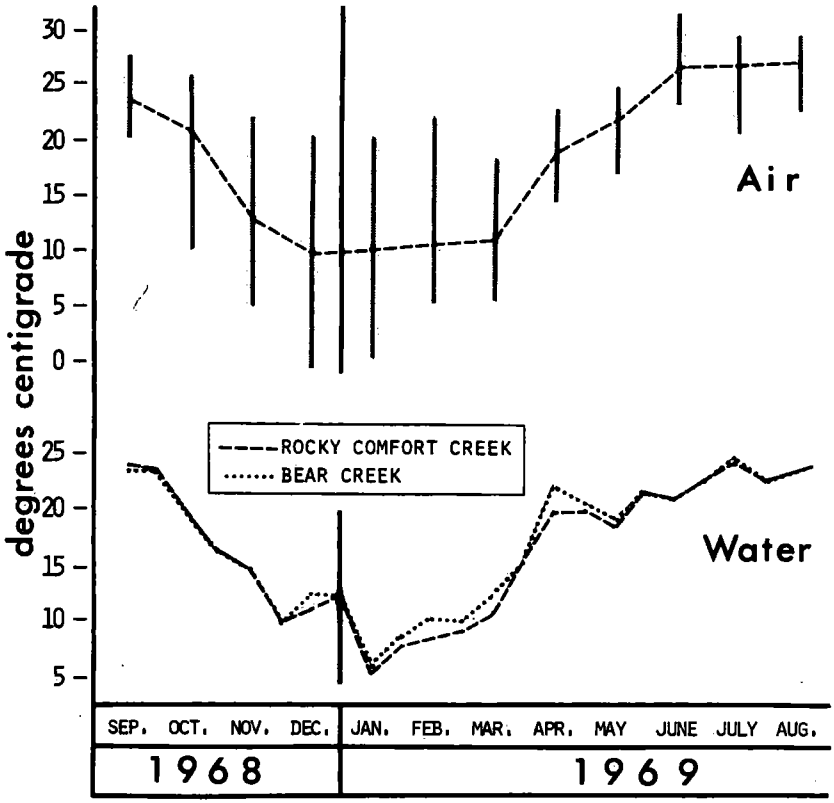

FIGURE 7.—Monthly air and water temperatures at the study areas, September 1968 to August 1969. The dotted lines show monthly temperature ranges.

and free carbon dioxide content was fairly constant throughout the year (Fig. 8).

The substratum of the sampling area supported no vegetation except for thick growths of the water moss, *Leptodictyum riparium*, and a filamentous algae, *Spirogyra* sp. in a narrow strip at the upper reaches. Along the marsh zone of the station were plant communities composed of *Panicum regidulum, Scirpus cyperinus, Solidago altissimum.*, and *Pluchea camphorata.*

BEAR CREEK

Bear Creek is basically the same as Rocky Comfort Creek, but its substratum is mainly coarse shifting sand and it has no cascades. The streams are confluent near the main outlet. Bear Creek flows approxi-

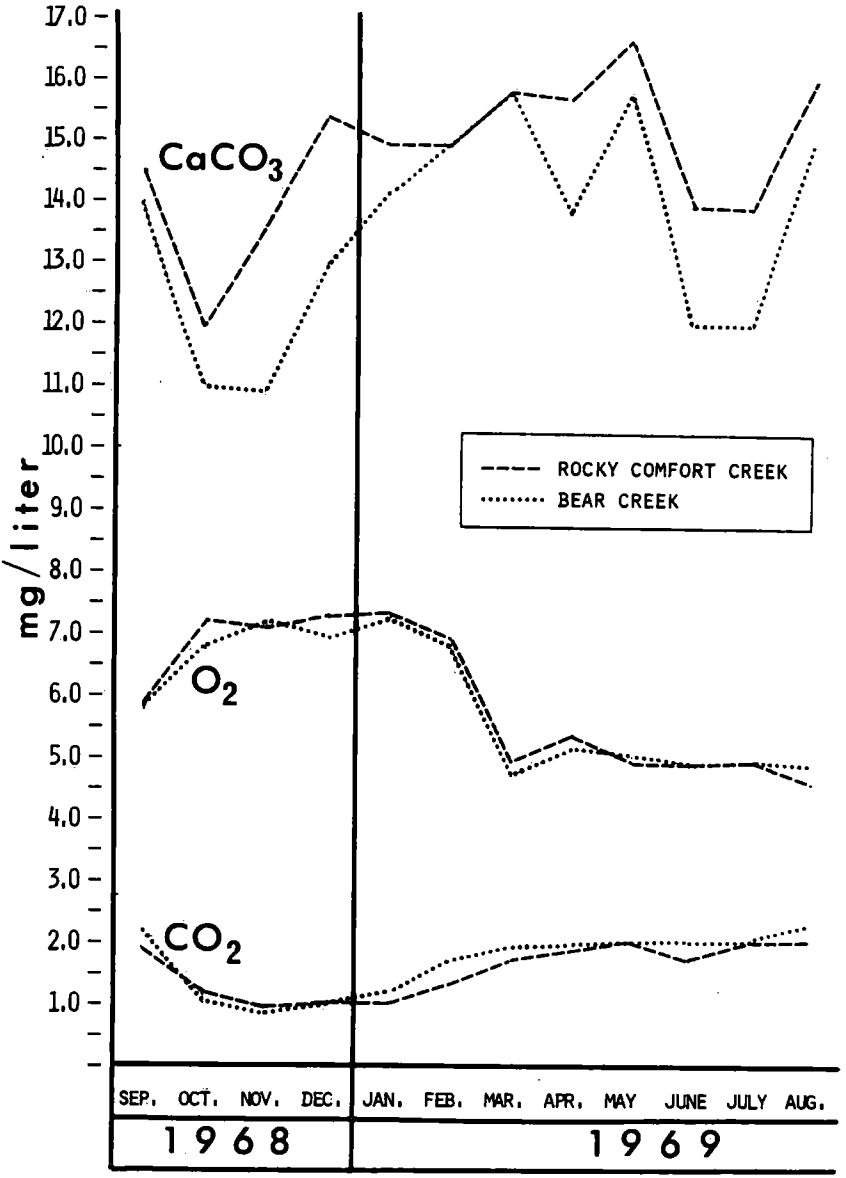

FIGURE 8.—Monthly calcium carbonate, dissolved oxygen, and free carbon dioxide content of Rocky Comfort and Bear Creeks, September 1968 to August 1969.

mately 10.2 miles and averages 21 feet wide. Typical of most sand-bottomed streams, the substratum supports no vegetation. Woody plants growing along the banks are the principle source of organic detritus.

A permanent station, mainly for ecological observations, was 1.9 miles from the mouth of the stream and measured approximately 20 feet by 15 feet (Fig. 4 B). The current velocity ranged from 0.8–1.2 feet per second. Water temperatures were similar to Rocky Comfort Creek (Fig. 7); Figure 8 shows chemical and physical characteristics. Except for scattered growths of *Leptodictyum riparium* and *Spirogyra* sp. at the submerged concrete wall of the bridge, the sampling area substratum was relatively bare. Plants growing in the marsh zone were similar to those found at Rocky Comfort Creek.

Relationships and Geographical Distribution of Baetisca rogersi

The genus *Baetisca,* established by Walsh (1862) for the species *Baetisca obesa* (Say), was known only form imagos until Walsh (1864) reared the nymphs. *Baetisca* represents a monobasic family Baetiscidae which was first recognized by Eaton (1883) as "Section 11 of *Baetisca.*" Authorship of the name was established by Lameere (1917) as tribe Baetiscini. Subsequently the family has been universally recognized at hierarchic levels of subfamily to family.

Baetisca is a highly specialized genus as indicated in the phylogeny presented by Edmunds (1962). The nymphs of the genus are distinguished by the presence of a massive mesothoracic shield which functions as a gill chamber (Fig. 3) and a greatly enlarged labial submentum (Fig. 15 E). The anal area of the fore wings of the imagos is greatly enlarged with only two anal veins present (Fig. 24 A). Vein CuA of the fore wings is unbranched and both veins CuA and CuP terminate before the anal angle (Fig. 24 A). The penes of the male imago are cone-shaped and apically divided (Fig. 24 E, F). The genital forceps of the male imagos are two-segmented, with the first segment indented giving the appearance of segmentation (Fig 24 E). Since Traver (1931), however, all major accounts of *Baetisca* indicate the forceps of the male imagos to be three-segmented except two drawings of Traver (1935) which show only two segments. This led to the study of the genital forceps of the males of all species of *Baetisca* available to us, and we found that the genital forceps consist of two segments (Pescador and Peters 1971).

Species of *Baetisca* occur only in North America with the center of diversification in eastern North America, especially the southeast. The following list gives known species, recognized synonymies, and general distribution of the species:

B. bajkovi Neave, 1934. Manitoba, Quebec, Illinois, Missouri, West Virginia, Tennessee.
B. becki Schneider and Berner, 1963. Florida.
B. callosa Traver, 1931. Quebec, New York, West Virginia.
B. carolina Traver, 1931 (=*B. thomsenae* Traver, 1937). Quebec, West Virginia, Tennessee, North Carolina, Georgia.
B. columbiana Edmunds, 1960. Washington.
B. escambiensis Berner, 1955. Florida.
B. gibbera Berner, 1955. Georgia, Florida.
B. lacustris McDunnough, 1932. Ontario, Quebec, New Brunswick, Michigan, Illinois.
B. obesa (Say, 1839) (*Baetis*). New Hampshire, New York, Michigan, Illinois, Georgia, Florida, Mississippi, California (?).
B. rogersi Berner, 1940. Georgia, Alabama, Florida, South Carolina.
B. rubescens (Provancher, 1876) (*Cloe*). Quebec.

Berner (1940) described *B. rogersi* from specimens he collected and reared in northwest Florida. Later Berner (1955) keyed the nymphs and imagos of the species in his revision of the southeastern species of *Baetisca*.

The relationship of *B. rogersi* to other species in the southeast will not be fully understood until the nymphs and imagos of all species are known and studied. Berner (1940) pointed out that *B. rogersi* appears to be related to *B. carolina* and based this conclusion on similarities in male genitalia and wing coloration of the imagos, the absence of dorsal spines on the mesonotum of the nymphs, and the similarity of mouthparts in the nymph.

Later Schneider and Berner (1963) described a new speices, *B. becki*, and suggested it was most closely related to *B. rogersi* based upon morphological similarities of the nymphs. Schneider and Berner (1963) gave six morphological characters to separate the nymphs, but Pescador and Peters (1971) pointed out that the presence of ventral spots (Fig. 9 A, B) and the relatively smaller size of *B. becki* are the best of the key characters delineating nymphs of *B. becki* from *B. rogersi*. Furthermore Pescador and Peters (1971) indicated that body size, color pattern, and structure of the male genital forceps are good characters to delineate the imagos of these two species. We agree with Schneider and Berner (1963) that *B. becki* and *B. rogersi* are closely related.

Little is known about the ecology and habits of *B. becki*. Schneider and Berner (1963) collected nymphs from swift-flowing, shallow, sand bottom streams with a constant pH of 5.4 in March and May; the nymphs lived into June. We have collected nymphs of *B. becki* and *B. rogersi* in April and May and adults of both species in May from the Blackwater River, Okaloosa County, Florida.

The known distribution of *B. becki* is extreme northwestern Florida. *B. rogersi* occurs throughout northwest Florida, southeastern Alabama,

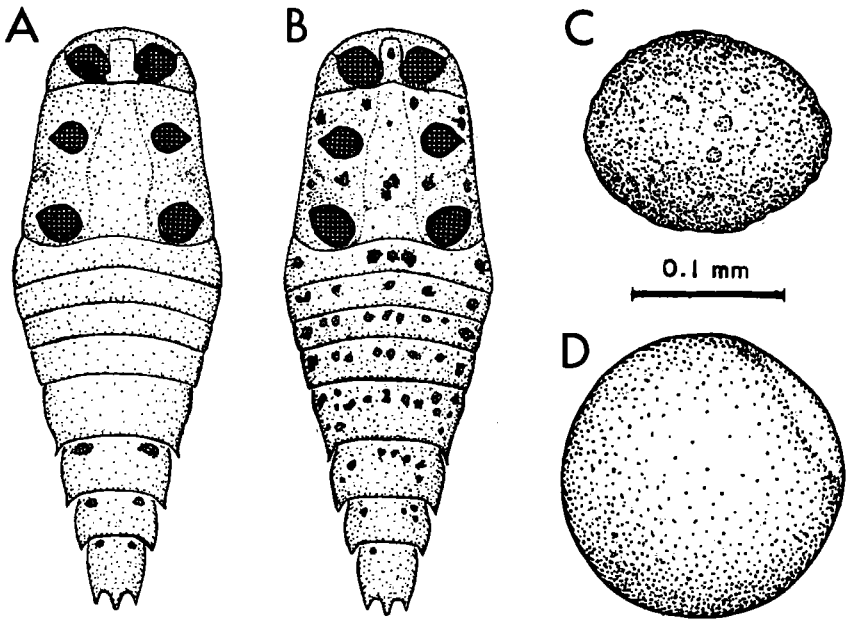

FIGURE 9.—Ventral color patterns: A) *B. rogersi;* B) *B. becki.* Eggs of *B. rogersi*: C) newly laid egg; D) mature egg.

Georgia, and western South Carolina (Fig 6 A). New range extensions are from the following localities: Georgia, Cherokee Co., upper Etowah River at St. Route S-2551, E. T. Hall; and South Carolina, Oconee Co., Chattooga River at Hwy. 76, 26 June 1971, P. H. and N. F. Carlson.

LIFE HISTORY AND ECOLOGY

In order to study in detail the ecology and seasonal distribution of *Baetisca rogersi*, the various life history stages (eggs, nymphal instars, subimagos, and imagos) must be determined and described and the habits and habitats of each stage must be known. Because of the extreme difficulty in conducting life history studies in the stream environment, rearings were completed only in the laboratory.

THE EGGS

EXTERNAL MORPHOLOGY

Mature egg (Fig. 9 C,D): Diameter 0.2-0.3 mm; opaque white; spherical without polar caps; chorion smooth, with no sculpturing; attachment structures consist of networks of sticky fibers on surface of chorion.

TABLE 1.—NUMBER OF DAYS FOR THE *Baetisca rogersi* EGGS TO START HATCHING UNDER LABORATORY CONDITIONS.

Date eggs extracted	No. of eggs	Fertilized or unfertilized	Date of hatching	Minimum incubation time	No. of nymphs		Average water temp. C
					Actual	%	
1968							
April 27	2726	unfertilized	May 28	31 days	9	0.33	24.3°
April 27	2539	unfertilized	May 28	31 days	41	1.61	24.3°
April 29	2137	fertilized	May 19	20 days	82	3.83	24.8°
May 8	2800	fertilized	May 30	22 days	21	0.76	24.2°
May 11	1590	fertilized	May 31	20 days	36	2.26	24.3°
May 13	1876	fertilized	June 2	20 days	26	1.39	22.1°
June 30	1721	unfertilized	July 24	24 days	10	0.57	21.3°
1969							
March 11	2650	unfertilized	March 31	20 days	19	0.72	21.3°
March 28	2600	fertilized	April 20	23 days	154	5.92	22.0°
April 1	2551	unfertilized	April 28	27 days	38	1.48	22.0°

Average no. days unfertilized = 26.6
Average no. days fertilized = 21.0

Mature eggs flatten when in clumps or clusters on the bottom of an incubation dish. The sticky nature of the egg surface probably serves to attach them securely to the substratum of the stream. Smith (1935) studied the eggs of *B. obesa* and *B. carolina* and also found a smooth chorion without sculpturing. Newly laid eggs of *B. rogersi* are subspherical with average measurements of 0.1 mm × 0.2 mm (Fig. 9 C). The eggs are yellowish-white with a colorless chorion and contain a large mass of yolk. The change in egg shape from subspherical to spherical (Fig. 9 D) took place approximately 3-5 hours after oviposition. Compacting within the reproductive organs of the female imagos probably accounts for their subspherical shape on oviposition. Egg color changed from yellowish to opaque-white 9-12 hours after oviposition.

INCUBATION PERIOD

As shown in Table 1, the time required for eggs to begin hatching in the laboratory (water temperatures 20° to 32.2° C) ranged from 20-31 days. The percentage of nymphs hatched was quite low for both the fertilized and unfertilized eggs compared with results of other workers (Degrange 1960, Elliott 1972). We did not have temperature control equipment, and suspect our results would have been quite different if we had. Bohle (1968) gives an account of morphogenesis in eggs of *Baetis rhodani* (Pictet) and *B. vernus* Curtis, and shows the effects of temperature on development in different stages. Our laboratory data

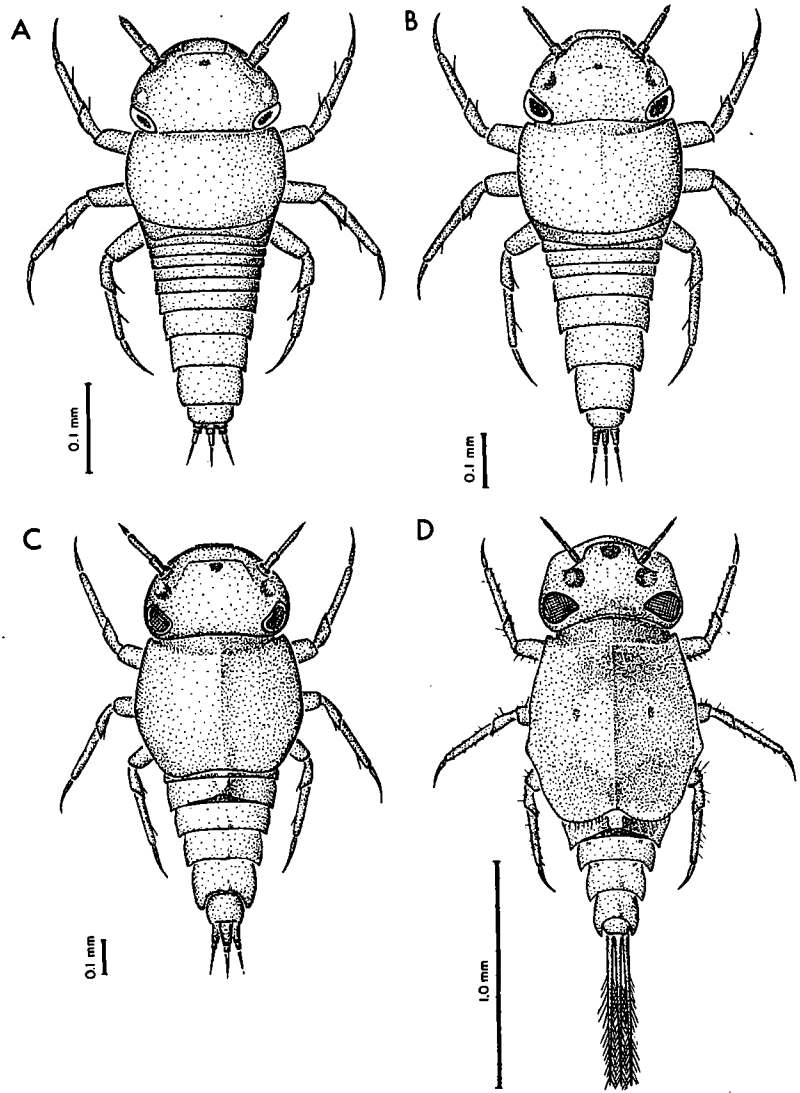

FIGURE 10.—Nymphal instars of *B. rogersi*: A) first instar; B) second instar; C) third instar; D) fourth instar.

scarcely begin to show the possibilities inherent for development in mayfly eggs, nor will it account for the seasonal pattern of nymphal instars of *Baetisca rogersi* (Tables 3 and 4) discovered in field work.

Fertilized eggs averaged 21.0 days while unfertilized eggs required an average of 26.6 days to begin hatching. Degrange (1960), who also found that unfertilized eggs took longer to hatch in six European species

of other genera, attributed the longer incubation period to delays and irregularities at the beginning of segmentation in the embryonic development.

The eggs did not all hatch at once. The duration of hatching in the laboratory extended from 7-17 days. As the eggs often formed clusters or clumps in the bottom surface of the dish, the eggs in the center of the cluster might obtain less oxygen. In nature, the eggs probably drift downstream far enough to be well dispersed. Attachment surfaces for the eggs are certainly plentiful on the rough stream bottom.

THE NYMPHS

EXTERNAL MORPHOLOGY

We found 12 nymphal instars in *Baetisca rogersi*. A set of morphological characters distinguish the first 11 instars, and all 11 descriptions are consistent and comparable. The twelfth instar nymphs are described fully. Recognizable differences between male and female nymphs first occur in the sixth instar. All characters described refer to both males and females unless otherwise noted.

First Instar Nymphs (Fig. 10 A): Body Length 0.40-0.60 mm; width of head 0.09-0.14 mm; thoracic notal shield: length 0.09-0.14 mm, width 0.15-0.19 mm; caudal filaments 0.05-0.07 mm. Head: opaque white, anterior margins smooth and dome-shaped. Compound eyes black and subspherical. Three ocelli present, all small, grayish, pale near margins. Antennae subequal to 1/2 length of head, 4-segmented, segment 2 longer than segments 1, 3, and 4 combined. Thorax: dorsum of thorax with transparent semirectangular notal shield which covers the entire surface of pronotum and metanotum; anterior margin of thoracic notal shield a little concave and smooth, lateral and posterior margins bare and a little convex; dorsal surface flat and bare. Legs: opaque; pro-, meso-, and metathoracic legs similar; femora cylindrical and bare; tibiae 1-segmented with a long spine on inner margin near apex; tarsi with a long spine on inner median margin; claws long, slender, without denticles. Abdomen: 10 visible tergal segments; first 5 segments subequal in length, compact, combined length equal to 1/3 total length of abdomen; posterolateral corners of terga 6-9 angular. Caudal filaments: whitish and bare; 4 short visible segments; apex of each filament thread-like, median filament a little longer than cerci.

Newly hatched nymphs were very active. First instars were colorless and opaque, and the whole body was filled with yolk globules. Immediately after eclosion, the young nymphs started to move either by crawling or swimming freely with strong undulations of the abdominal segments and caudal filaments.

Molting occurred 2-4 days after eclosion, the duration of the first instar averaging 3.2 days.

Second Instar Nymphs (Fig. 10 B): Body length 0.65-0.85 mm; width of head 0.15-0.20 mm; thoracic notal shield: length 0.13-0.21 mm, width 0.20-0.27 mm; caudal filaments 0.08-0.12 mm. Head: opaque white; a little flattened; frontal process a little developed with the anterior margins smoothly arched. Compound eyes a little larger than those of the first instar nymphs. Ocelli more prominent and slightly darker than those of first instar nymphs. Antennae whitish, 4-segmented with segment 2 greatly elongated. Thorax: posterior margin of metanotum overlapping abdominal segments 1 and 2; anterior margin of the thoracic notal shield a

little concave and smooth; anterolateral corners angular; lateral and posterior margins bare and a little convex; median carina of thoracic notal shield indistinct. Legs: color, shape, and structure as in first instar. Abdomen: opaque; abdominal tergal segments 1 and 2 partially fused; posterolateral corners of segments 6-9 more developed and sharply pointed than those of first instar nymphs; segment 9 elongated and cylindrical. Caudal filaments: color and number of segments as in first instar nymphs; median filament subequal to cerci.

Ecdysis of the second instar occurred after 3-5 days.

Third Instar Nymphs (Fig. 10 C); Body length 0.90-1.30 mm; width of head 0.23-0.29 mm; thoracic notal shield: length 0.30-0.48 mm, width 0.60-0.80 mm; caudal filaments 0.30-0.39 mm. Head: pale white; anterior margin of frontal process a little curved near base of antennae. Compound eyes: inner margin angular, facets clearly defined. Ocelli more distinct, prominent, larger than those of the second instar nymphs. Antennae: grayish-white. Thorax: posterior margin of thoracic notal shield truncate, extending to near posterior margin of abdominal segment 5, median carina distinct and more prominent than in second instar nymphs, devoid of elevations. Legs: whitish; shape and structure as in second instar nymphs. Abdomen: whitish; tergal segments 1 and 2 fused; gills 1 and 2 present; pyramidal structure on tergum 6 weakly developed; posterior margin of tergum prominently excavated to receive the small rounded anterior margin of tergum 10; small dorsal tubercles at mid-posterior margin of terga 7-9 and appear as simple elevations; posterolateral spines present on segments 6-9. Caudal filaments: color and structure of filaments as in second instar nymphs.

Duration of the third instar is unknown as all nymphs died in the laboratory.

Fourth Instar Nymphs (Fig. 10 D): Body length 1.40-1.80 mm; width of head 0.30-0.50 mm; thoracic notal shield: length 0.55-0.70 mm, width 0.80-1.20 mm; caudal filaments 0.30-0.40 mm. Head: pale white; genae well developed; frontal process extends anteriorly and almost overlaps the anterior margin of head. Compound eyes: inner margin sharply angulated. Ocelli larger than those of third instar, black. Antennae: pale white; 5-segmented. Thorax: thoracic notal shield pale white, uniformly washed with light brown along median line; median carina more distinct than that of third instar nymphs, devoid of elevations as in third instar nymphs; a small black macula on submedian surface; anterolateral corners with a distinct notch; lateral spines present and appear as simple lateral projections; posterior margin with long hair, a little truncate near the median carina and elevated into a roof-like structure. Sternum of thorax washed uniformly with brown. Legs: pale yellow; small spines present inner margins of tibiae and tarsi; outer margins covered with long hairs; tarsal claws more curved than those in third instar. Abdomen: abdominal gills 1-4 present; abdominal terga 1-6 whitish; pyramidal structure of abdominal segment 6 excavated along its median surface and lies in the excavation of the posterior margin of the thoracic notal shield; abdominal terga 7-10 pale yellow; small, weakly developed, dorsal median projections on terga 7-9; posterolateral spines on segments 6-9, spines on segment 9 curved inwardly embracing tergum 10. Sterna 1-6 washed uniformly with brown, sterna 7-10 pale yellow; subanal plate triangular apically. Caudal filaments: pale yellowish; apical 2/3 thickly fringed with hairs.

The duration of the fourth instar is unknown. All nymphs in this stage were collected in the study areas, and molted after 2-5 days in the laboratory.

Fifth Instar Nymphs (Fig. 11 A): Body length 1.80-2.30 mm; width of head 0.50-0.70 mm; thoracic notal shield: length 0.80-1.20 mm, width 1.30-1.90 mm; caudal filaments 0.50-0.80 mm. Head: light brown, with uniform, minute black stipplings; a prominent black spot below base of compound eyes near lateral margins of head; a small frontal prominence present below frontal projection of the head; genae greatly extended anterolaterally. Compound eyes: triangular with inner and outer posterolateral corners angular. Ocelli smaller in relation to size of compound eyes than those in the fourth instar nymphs. Antennae: color and number of segments as in the fourth instar nymphs. Thorax: thoracic notal shield yellowish-brown,

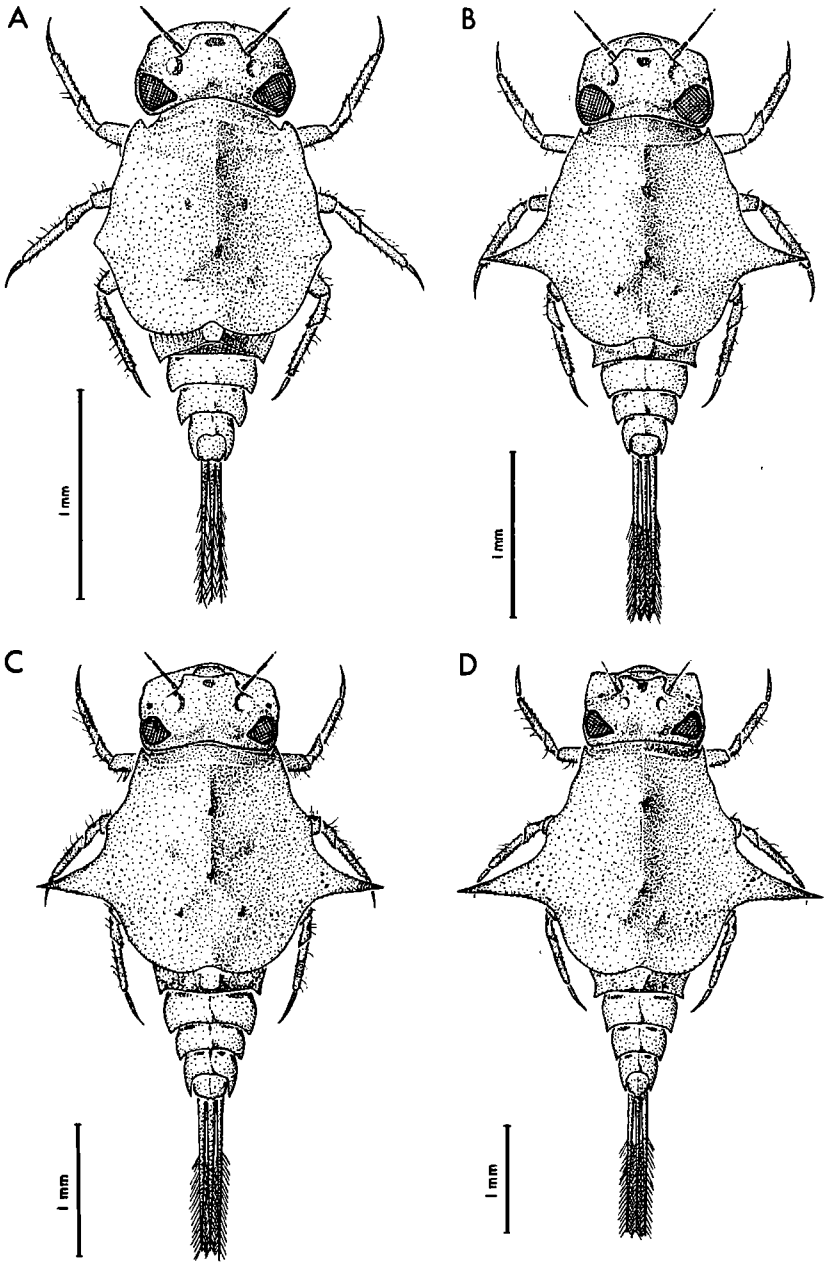

FIGURE 11.—Nymphal instars of *B. rogersi*: A) fifth instar; B) sixth instar; C) seventh instar; D) eighth instar.

entire shield with uniform, minute, black stipplings; two small elevations present along median carina; paired dorsal submedian spines near posterior 1/3 of shield; anterolateral corners notched to receive head; lateral spines more distinct and prominent than those of fourth instar nymphs; lateral extensions distinct. Sternum yellowish-brown. Legs: color pattern as in fourth instar nymphs except lateral margins brown; shape and structure of legs as in fourth instar nymphs. Abdomen: abdominal gills 1-6 present; abdominal terga 1-5 pale; base of pyramidal projection of tergum 6 brown; terga 7-10 pale yellow; small median knob-like projections on terga 7-9; median line of terga 7-9 brown, except projections pale; posterolateral spines on segments 6-9. Abdominal sterna 1-6 yellowish brown, remainder of segments pale; subanal plate triangular apically. Caudal filaments: basal 1/3 of caudal filaments grayish-brown, remainder pale yellow; apical 2/3 of caudal filaments fringed with long hair, remainder bare.

The fifth instar molted after 10-12 days, averaging 11.5 days.

Sixth Instar Nymphs (Fig. 11 B): Body length of male 2.30-3.40 mm; width of head 0.60-0.90 mm; thoracic notal shield: length 1.20-1.70 mm, width 1.90-3.10 mm; caudal filaments 0.60-1.19 mm. Body length of female 2.30-3.50 mm; width of head 0.60-1.00 mm, thoracic notal shield: length 1.20-1.90 mm, width 1.90-3.00 mm; caudal filaments 0.60-1.18 mm. Head: color and markings as in fifth instar nymphs, except dark brown macula more prominent near anterior base of compound eyes; anterior projection of frontal process of head poorly developed; shape of frontal prominence of head as in fifth instar nymphs; genae greatly expanded with anterolateral corners distinctly angular. Compound eyes: black; inner posterolateral cor-

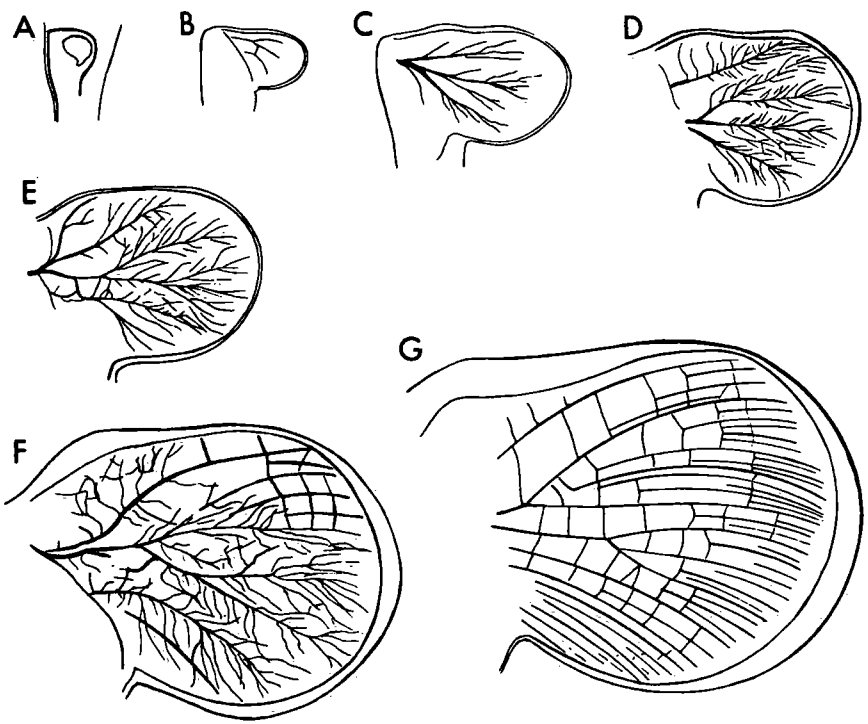

FIGURE 12.—Hind wing pad development of nymphal instars of *B. rogersi*: A) sixth instar; B) seventh instar; C) eighth instar; D) ninth instar; E) tenth instar; F) eleventh instar; G) twelfth instar.

ners of eyes of females rounded. Size and shape of lateral ocelli as in fifth instar nymphs; median ocellus smaller than lateral ocelli. Antennae: pale, 6-segmented. Thorax: thoracic notal shield light brown with uniform minute black stipplings; elevation of median carina greatly produced and prominent; paired dorsal spines distinct and subequal in length to posterior elevation of median carina; anterolateral corners brown, spinous; lateral spines well developed, sharply pointed, brown at apex; size of lateral extensions of notal shield as in fifth instar nymphs. Hind wing pads poorly developed, lobe-like as in Figure 12 A. Sternum light brown, darker at lateral margins. Legs: yellowish-brown; a dark brown macula near base of dorsal surface of tibiae; tarsi with a median transverse brown band, inner margins with one row of small spines. Abdomen: terga 1-5 pale, tergum 6 light brown, anterolateral margins of each segment dark brown; mid-dorsal elevations on terga 7-9 prominent, pale; posterolateral spines present on segments 6-9. Abdominal sterna 1-6 brown, remainder of segments pale; a brown macula present near anterolateral corners of sterna 7-9; subanal plate triangular apically. Caudal filaments: basal 1/3 and apical 1/2 of caudal filaments brown, remainder paler; apical 2/3 of caudal filaments fringed with long hairs.

Ecdysis of the sixth instar occurred in 11-14 days, averaging 12.5 days.

Seventh Instar Nymphs (Fig. 11 C): Body length of male 3.10-4.40 mm; width of head 0.90-1.30 mm; thoracic notal shield: length 1.70-2.40 mm, width 2.50-4.20 mm; caudal filaments 0.80-1.50 mm. Body length of female 3.20-4.50 mm; width of head 1.00-1.40 mm; thoracic notal shield: length 1.70-2.40 mm, width 2.80-4.20 mm; caudal filaments 0.80-1.50 mm. Head: light brown except posterolateral areas near base of compound eyes brown; a transverse ridge present between compound eyes near posterior margins of vertex; a prominent black macula near anterior base of compound eyes; anterior projection of frontal process of head more prominent than that of the sixth instar nymphs; basal 1/3 of frontal prominence overlapped dorsally by frontal projection of head; anterolateral corners of genae angular. Compound eyes: grayish-black; eyes of males larger than those of females with the inner posterolateral corners of eyes of females smooth and rounded. Size and shape of lateral ocelli as in sixth instar nymphs. Antennae: pale; 6-segmented. Thorax: thoracic notal shield light brown with distinct black tubercles; elevation of median carina more developed than that of the sixth instar; dorsal spines prominent and cone-shaped; anterolateral corners brown and spinous; posterior 2/3 of lateral margins of shield crenulate, more prominent near base of lateral spines; basal 2/3 of margins of lateral spines serrate; lateral extensions a little more distinct and prominent than those of the sixth instars. Hind wing pads small with three distinct longitudinal tracheae as in Figure 12 B. Sternum light brown; lateral margins darker. Legs: color pattern as in sixth instar nymphs except for the presence of minute brown stipplings on coxae, trochanters, and femora of prothoracic, mesothoracic, and metathoracic legs; a distinct dark brown macula near base of dorsal surface of tibiae; inner margins of tibiae and tarsi with one row of small spines; apex of tarsal claws reddish-brown. Abdomen: abdominal terga 1-5 pale; posterolateral areas of tergum 6 brown and covered with minute hairs; a continuous dark brown median line on terga 7-10, interrupted posteriorly on each tergum; anterior margins of terga 7-9 with a pair of broad, dark brown, transverse maculae which extend almost to median line. Prominent elevations or projections arise from mid-dorsum of terga 7-9; posterolateral spines present on segments 6-9. Sternum covered with setae; base of setae dark brown; sterna 1-6 brown, remainder of sterna yellowish-brown; a distinct dark brown macula near anterolateral corners of sterna 7-9; subanal plate as in sixth instar. Caudal filaments: basal 1/3 and apical 1/2 of caudal filaments smoky-brown, remainder pale; posterior 2/3 with long hairs.

Molting of the seventh instar occurred in 12-15 days, averaging 13.2 days.

Eighth Instar Nymphs (Fig. 11 D); Body length of male 3.70-5.50 mm; width of head 1.20-1.50 mm; thoracic notal shield: length 2.20-2.80 mm, width 3.20-4.70 mm; caudal filaments 1.30-1.70 mm. Body length of female 3.90-5.60 mm; width

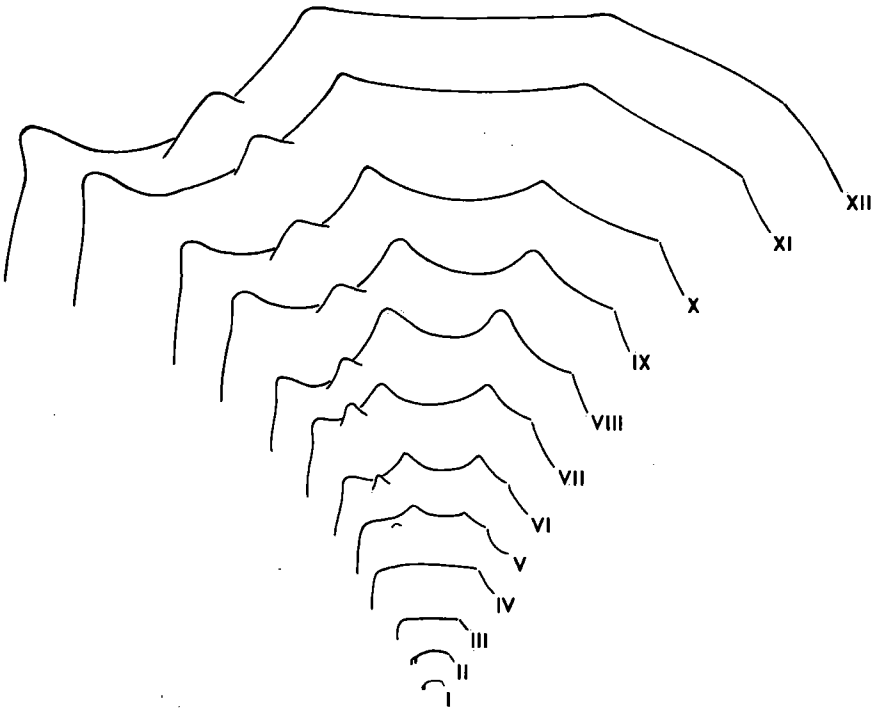

FIGURE 13.—Lateral views of the thoracic notal shield of *B. rogersi* nymphs. Roman numerals refer to nymphal instars.

of head 1.20-1.50 mm; thoracic notal shield: length 2.20-2.80 mm, width 3.50-4.60 mm; caudal filaments 1.30-1.80 mm. Head: light brown with minute black stipplings, a prominent transverse ridge between compound eyes near posterior margin of vertex; a distinct black macula near anterior base of compound eyes near posterior margin of vertex; lateral borders of genae weakly crenulated with the anterolateral corners angular; anterior projections of frontal process of head more developed than those of the seventh instar nymphs; basal 1/2 of frontal prominence of head dorsally covered by the frontal process. Compound eyes: grayish-black; posterolateral corners of inner margins of eyes of males angular and larger than those of females; inner posterolateral corners of eyes of females rounded and smooth. Ocelli black, relatively smaller than those of the seventh instar nymphs; median ocellus equal in size to lateral ocelli. Antennae: yellowish; 7-segmented. Thorax: thoracic notal shield light brown with dark brown tubercles and minute black stipplings, smaller tubercles along areas near median carina, larger tubercles around base of lateral spines; elevation of median carina and paired dorsal spines as in Figure 13 VIII; lateral borders of shield near base of lateral spines light brown except apex reddish-brown; basal 2/3 of margins of lateral spines serrate; size and shape of lateral extensions as in seventh instar. Hind wing pads with numerous tracheal branches as in Figure 12 C. Sternum light, lateral margins brown. Legs: brown except tibiae and tarsi pale; apex of tarsal claws reddish-brown; a prominent dark brown macula near base of dorsal surface of tibiae; tarsi with a broad, median, transverse, dark brown band, margins with one row of small sharp spines. Abdomen: terga 1-5 pale; posterior 1/2 of tergum 6 brown, darker around base of pyramidal structure, remainder of tergum pale; terga 7-10 yellowish-brown with minute dark brown setae; a

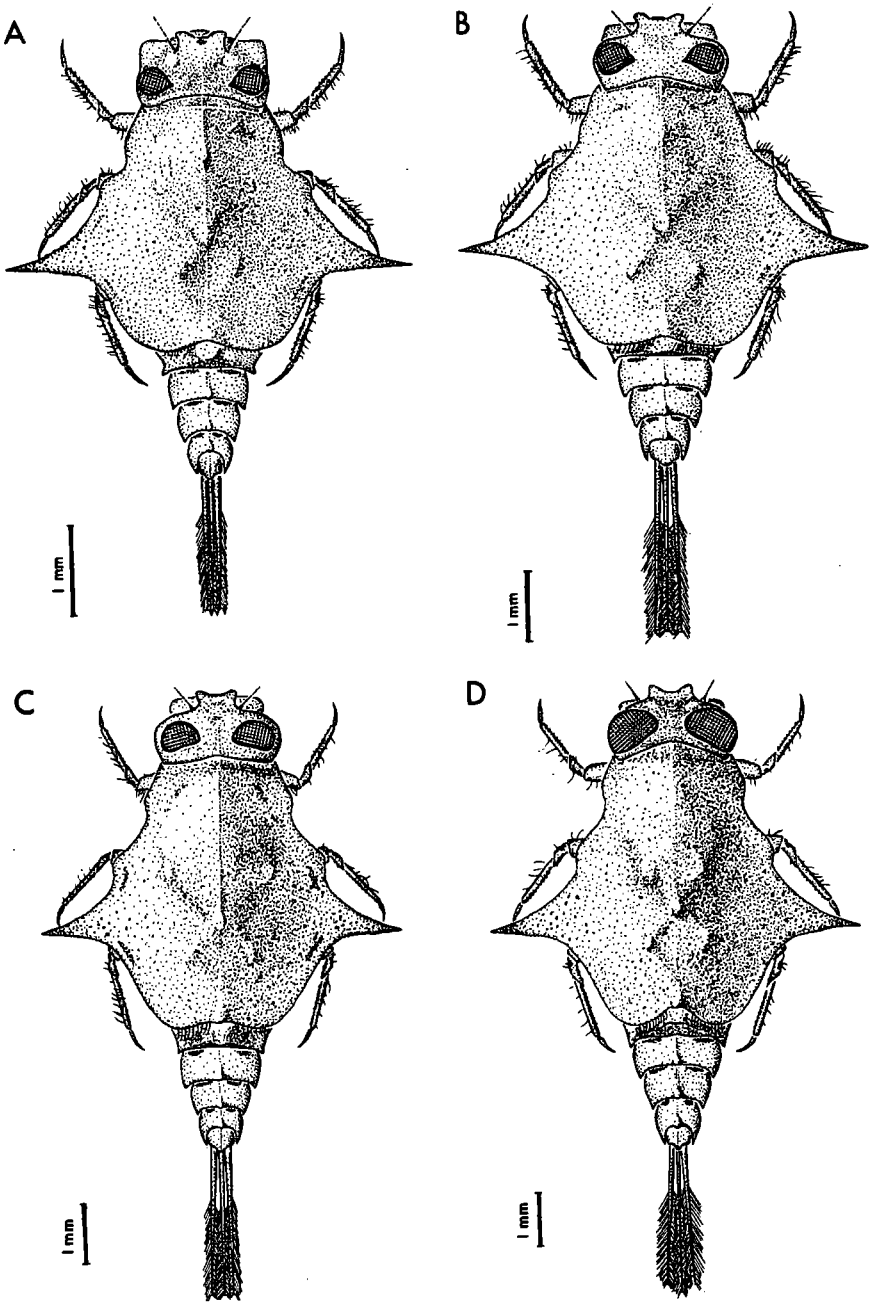

FIGURE 14.—Nymphal instars of *B. rogersi*: A) ninth instar; B) tenth instar; C) eleventh instar; D) twelfth instar.

continuous dark brown median line on terga 7-10, interrupted posteriorly on each tergum; anterior margins of terga 7-9 with a pair of broad, dark brown, transverse maculae extending to median line, elevations at mid-dorsum of terga 7-9 prominent and pointed; posterolateral spines present on segments 6-9. Color and markings of sternum as in seventh instar nymphs; submedian plate slightly cleft apically. Caudal filaments: basal 1/3 smoky brown, remainder pale; posterior 2/3 of caudal filaments with long brownish hairs.

The eighth instar lasted for 14-16 days, averaging 14.8 days.

Ninth Instar Nymphs (Fig. 14 A): Body length of male 4.50-6.50 mm; width of head 1.40-1.90 mm; thoracic notal shield: length 2.70-4.30 mm, width 3.80-5.50 mm; caudal filaments 1.40-1.50 mm. Body length of female 4.70-6.60 mm; width of head 1.40-1.80 mm; thoracic notal shield: length 2.80-4.30 mm, width 3.90-6.20 mm; caudal filaments 1.60-2.07 mm. Head: brown with numerous minute black stipplings; black macula near anterior base of compound eyes partly covered dorsally by the anterolateral margins of eyes; lateral borders of genae crenulated; anterior projection of frontal process of head greatly extended forward; basal 1/3 of frontal prominence of head dorsally covered by the frontal process. Compound eyes: black, larger than those of the eighth instar nymphs; shape of inner margins of posterolateral corners of eyes of males and females as in eighth instar nymphs. Ocelli greatly reduced, inconspicuous. Antennae: yellowish; 7-segmented. Thorax: thoracic notal shield light brown with numerous dark brown tubercles and minute black stipplings, areas adjacent to median carina darker in males, dark brown tubercles more abundant on males; elevations of median carina and paired dorsal spines as in Figure 13 IX; lateral borders of shield crenulated and serrated near base of lateral spines; basal 2/3 of margins of lateral spines serrate; lateral spines light brown except reddish-brown at apex; lateral extensions more prominent than those of eighth instar. Hind wing pads with longitudinal tracheae and numerous small tracheal branches (Fig. 12 D). Sterna brown with minute dark brown setae. Legs: light brown, coxae darker, apex of tarsal claws reddish-brown; a prominent broad dark brown macula near base of dorsal surface of tibiae; tarsi with a broad, median, transverse, dark brown band. Inner margins of tibiae and tarsi with one row of spines. Abdomen: terga 1-5 pale; posterior 1/2 of tergum 6 dark brown, almost black around base of pyramidal structure, remainder pale; posterior border of tergum 6 with small black tubercles; terga 7-10 light brown with dark brown tubercles; a prominent continuous dark brown median line on terga 7-10, interrupted posteriorly on each tergum; anterior margin of terga 7-9 with a pair of dark brown transverse maculae extending almost to median line; elevations at mid-dorsum of terga 7-9 pale, more prominent than those in the eighth instar nymphs; posterolateral corners of terga 6-9 with spines. Sterna light brown; lateral borders of sterna 1-6 brown with minute setae, base of setae dark brown; sterna 1-7 with a network of black stipplings; a dark brown macula near anterolateral corners of sterna 7-9; subanal plate cleft apically. Caudal filaments: pale except basal 1/3 of median filament and lateral margins of cerci reddish-brown; posterior 2/3 of caudal filaments with long brownish hairs.

The ninth instar molted after 14-16 days, averaging 15.2 days.

Tenth Instar Nymphs (Fig. 14 B): Body length of male 5.40-7.50 mm; width of head 1.60-2.00 mm; thoracic notal shield: length 3.20-4.60 mm, width 4.60-5.90 mm; caudal filaments 1.70-2.20 mm. Body length of female 5.70-7.50 mm; width of head 1.70-2.10 mm; thoracic notal shield: length 3.30-4.60 mm, width 4.70-6.10 mm; caudal filaments 1.80-2.20 mm. Head: brown, except borders of genae and anterior projections of frontal process pale; head with numerous small dark brown tubercles; a black macula near anterior base of compound eyes, partly covered by anterolateral margins of compound eyes; genae expanded, anterolateral corners angular and borders weakly crenulated; frontal process of head greatly extended beyond anterior margins of head; a distinct median carina on vertex and extended anteriorly through base of frontal process of head, continuous posteriorly to median carina of thoracic notal shield. Compound eyes: black, larger than those of the ninth instar nymphs;

eyes of males larger than those of females; inner margin of posterolateral corners of eyes of males angular; inner margin of posterolateral corners of eyes of females rounded. Ocelli obscured and marked by the absence of black tubercles over the area. Antennae: yellowish, 8-segmented; basal segment washed with brown. Thorax: color and markings of thoracic notal shield of males as in ninth instar nymphs, light brown in females except the anterior 1/2 near median carina washed with brown; numerous dark brown tubercles; elevation of median carina and paired dorsal tubercles as in Figure 13 X; lateral borders of shield crenulated, serrated at base of lateral spines; lateral spines pale, reddish-brown at apex; margins of lateral spines serrate. Hind wing pads as in Figure 12 E. Sterna light brown with numerous black setae. Legs: yellowish-brown except base of coxae washed with brown; margins of legs as in ninth instar nymphs. Abdomen: color pattern of terga 1-5 and markings of tergum 6 as in ninth instar nymphs; terga 7-10 light brown with numerous setae; base of setae dark brown, tuberculated; a prominent continuous dark brown median line on terga 7-10, interrupted posteriorly on each tergum; anterior margins of terga 7-9 with a pair of dark brown transverse maculae that extend almost to median line; elevations at mid-dorsum of terga 7-9 keel-shaped, approximately equal to 1/2 length of their respective terga; lateral borders of terga 6-9 weakly crenulated, crenulation weakest on tergum 6; posterolateral corners of terga 6-9 with spines more prominent than those of ninth instar nymphs. Sterna light brown, lightly washed with dark brown, with prominent black setae; sterna 1-7 with a minute network of black stipplings; black macula near anterolateral corners of sterna 7-9 more prominent than in ninth instar nymphs; subanal plate more deeply cleft than that of ninth instar. Caudal filaments: pale, except base of cerci light brown; basal 1/2 of median filament reddish-brown; posterior 2/3 of caudal filaments with long brownish hairs.

The tenth instar molted after 15-18 days, averaging 16.8 days.

Eleventh Instar Nymphs (Fig. 14 C): Body length of male 6.60-8.10 mm; width of head 2.00-2.20 mm; thoracic notal shield: length 3.90-4.80 mm, width 5.50-6.10 mm; caudal filaments 2.00-2.30 mm. Body length of female 6.70-8.50 mm; width of head 2.10-2.30 mm; thoracic notal shield: length 4.00-5:30 mm, width 5.70-6.30 mm; caudal filaments 2.00-2:40 mm. Head: color and markings as in tenth instar nymphs; dark brown tubercles on head of females more abundant than in males; genae expanded, anterolateral corners rounded and weakly crenulated; frontal process of head as in Figure 14 C, a distinct median carina on vertex and extended through base of frontal process of head, continuous posteriorly to median carina of thoracic notal shield. Compound eyes: black, eyes of males larger than those of females, inner margins of posterolateral corners of compound eyes of males as in Figure 14 C; inner margins of posterolateral corners of compound eyes of females rounded. Ocelli obscured. Antennae: yellowish, 9-segmented. Thorax: thoracic notal shield light brown, with numerous dark brown tubercles, fewer tubercles in males than in females: elevations of median carina and paired dorsal spines as in Figure 13 XI; lateral borders of shield crenulated, serrated at base of lateral spines; color and markings of lateral spines and lateral extensions as in tenth instar. Hind wing pads pale, light brown at margins (Fig. 12 F); base of hind wing pads of nymphs reddish-brown. Sterna light brown with small, black tuberculated setae. Legs: yellowish-brown except coxae washed with smoky-brown; margins of legs brownish; outer surface of femora with black tuberculated setae; apex of tarsal claws reddish-brown; a prominent dark brown macula near base of dorsal surface of tibiae; tarsi with a median, transverse, dark brown band; inner margins of tibiae and tarsi with one row of sharply pointed spines. Abdomen: terga 1-5 pale; posterior 1/2 of tergum 6 dark brown with black tubercles at posterior margins, almost black at basal 1/2 of pyramidal structure, dorsal concavities of pyramidal structure pale; terga 7-10 light brown with numerous black tuberculated setae; a prominent continuous dark brown median line on terga 7-10, interrupted posteriorly on each tergum; anterior margins of terga 7-9 with a pair of dark brown transverse maculae; median, dorsal elevations of terga 7-9 keel-shaped, approximately equal to 1/2 length of their respective terga; lateral

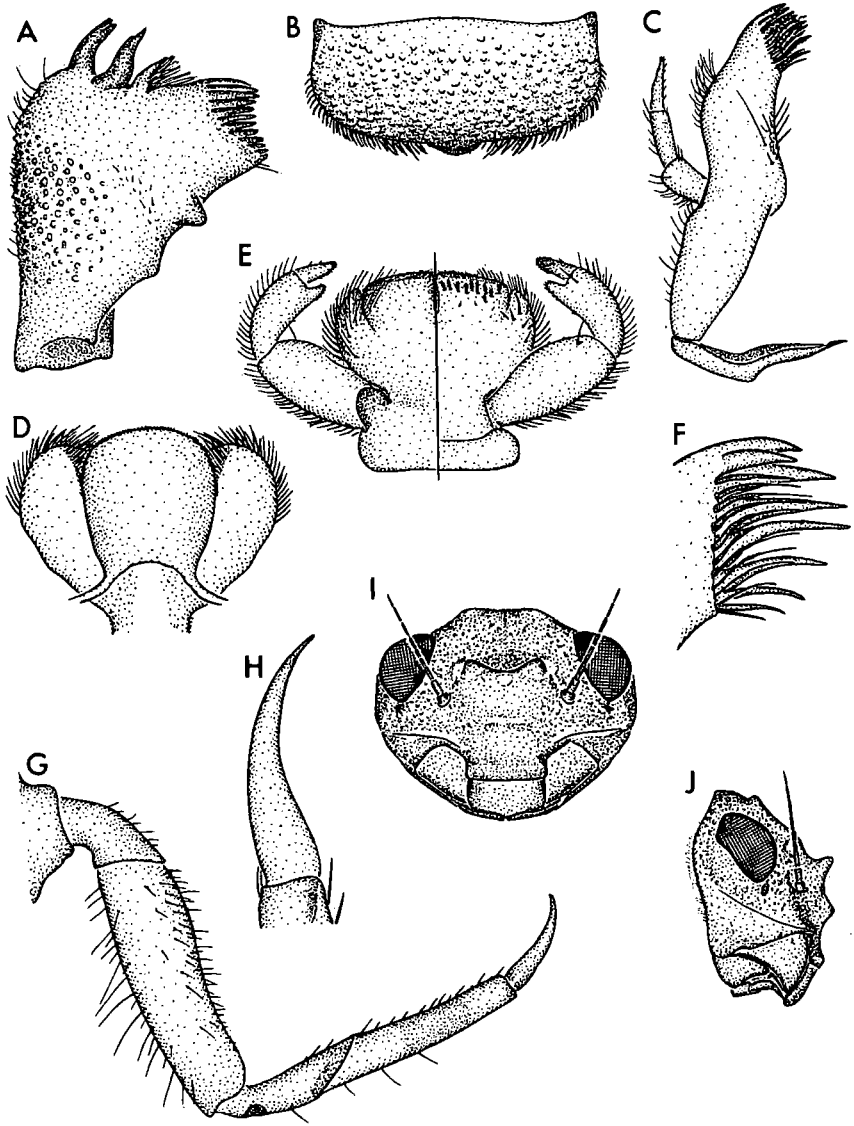

FIGURE 15.—Mature nymph of *B. rogersi*. A–F.—Mouthparts: A, left mandible; B, labrum; C, right maxilla, ventral view; D, hypopharynx; E, ventral (right) and dorsal (left) view of labium; F, apex of maxilla enlarged; G–H.—Fore leg and fore claw. I–J.—Frontal and lateral views of head of female nymph.

borders of terga 6-9 crenulated, crenulation weakest at tergum 6; posterolateral spines on terga 6-9. Sterna light brown with numerous black tubercles; lateral margins of sterna 1-5 brown; a small network of black stipplings present near posterior margins of sterna 1-8; size of black macula near anterolateral corners of sterna 7-9

as in tenth instar nymphs; posterior borders of sterna 6-9 weakly crenulated; subanal plate deeply cleft apically. Caudal filaments: cerci light brown, darker at base; proximal 2/3 of median filament yellowish brown; distal 1/2 of caudal filaments annulated; posterior 2/3 of caudal filaments with long brownish hair.

The eleventh instar molted after 16-18 days, averaging 17.6 days.

Twelfth Instar Nymphs (Fig. 14 D): Body length of male 6.80-8.90 mm; width of head 2.00-2.50 mm; thoracic notal shield: length 4.50-4.80 mm, width 5.90-6.60 mm; caudal filaments 2.10-2.50 mm. Body length of female 7.40-9.90 mm; width of head 2.20-2.60 mm; thoracic notal shield: length 4.30-5.70 mm, width 5.70-7.00 mm; caudal filaments 2.20-2.70 mm. Head: brown, except margins of genae and anterior projections of frontal process of head pale; head with numerous black tubercles; genae expanded, anterolateral corners of genae crenulated; anterior projection of frontal process of head as in Figure 14 D and 15 I, J. Compound eyes: grayish-black; eyes of males larger than females, almost occupying the entire dorsal area of the head. Ocelli obscured. Antennae: pale, basal segments darker; 9-segmented; antennal socket ringed with brown. Mouthparts (Fig. 15 A-F): labrum light brown (Fig. 15 B). Outer surface of mandibles with brownish papillae; left mandible as in Figure 15 A; molar surface of mandibles with 12-14 teeth; a sclerotized reddish-brown projection at base of molar area. Maxillae pale, except pectinate spines and teeth at distal margin of galea-lacinia reddish-brown; shape of pectinate spines and teeth of distal margin of galea-lacinia as in Figure 15 C,F; segment 2 of maxillary palpi subequal a little longer to 1 1/4 length of segment 1; segment 3 of palpi subequal in length to segment 2, apex acute; hair on maxillae as in Figure 15 C. Lingua of hypopharynx oval with minute setae along anterior margins; superlingua of hypopharynx as in Figure 15 D, with a row of long hairs along anterior margin. Labium light brown, except glossae darker: segment 2 of labial palpi 2/3 length to a little shorter than segment 1; segment 3 of palpi 1/3 length of segment 2; inner margin of distal corner of segment 2 finger-like; glossae as in Figure 15 E, anterior margin with minute hair, inner surface of glossae near distal margin with pectinate hairs; paraglossae as in Figure 15 E, with long hairs at lateral and anterior borders, inner surface of paraglossae near distal margin with spine-like hairs as in Figure 15 E. Thorax: thoracic notal shield brown, with numerous black tubercles, notal shield of males with fewer dark brown tubercles than those of the females; elevation of median carina and dorsal spines of thoracic notal shield as in Figure 13 XII, lateral borders of notal shield crenulated, serrated at base of lateral spines; lateral spines yellowish-brown at apex; lateral projections of notal shield as in Figure 14 D. Hind wing pads as in Figure 12 F; basal 1/3 of hind wing pads of newly molted nymphs reddish-brown, otherwise reddish-black, curled. Sterna light brown, with small black tuberculated setae; prosternum concave, posterior 1/4 of lateral borders indented to receive median coxal spur. Legs (Fig. 15 G,H): brownish-yellow except coxae brownish; outer surface of coxae and femora with black tubercles; a prominent dark brown macula near base on dorsal surface of tibiae; tarsi with a median, transverse, dark brown band; inner margins of tibiae and tarsi with one row of spines; tarsal claws as in Figure 15 H; reddish-brown at apex. Gills (Fig. 16): gill 1 as in Figure 16 A; dorsal portion of lamella long, pointed at posterior margin; ventral portion of lamella consists of ramified tracheal branches; tracheae grayish. Gill 2 as in Figure 16 B, with lamella flattened and expanded; gill 2 forms a protective covering for gills 3, 4, and 5. Gill 3 as in Figure 16 C; dorsal portion of lamella pointed at posterior margin; ventral portion of lamella consists of ramified tracheal branches arranged linearly along inner lateral border. Dorsal portion of lamella of gill 4 blunt at posterior end, tracheal branches as in Figure 16 D. Gill 5 as in Figure 16 E, shape as in gill 4. Gill 6 reduced, oval with the posterior 1/2 transparent and membranous as in Figure 16 F; gill 6 fits exactly into the concavity formed by the surface of the posterior elevation of the median carina and the dorsal groove of the pyramidal structure on tergum 6 (Fig. 20 A,B). Abdomen: terga 1-5 pale, completely concealed under thoracic notal shield; posterior 1/2 of tergum 6 dark brown with black tuber-

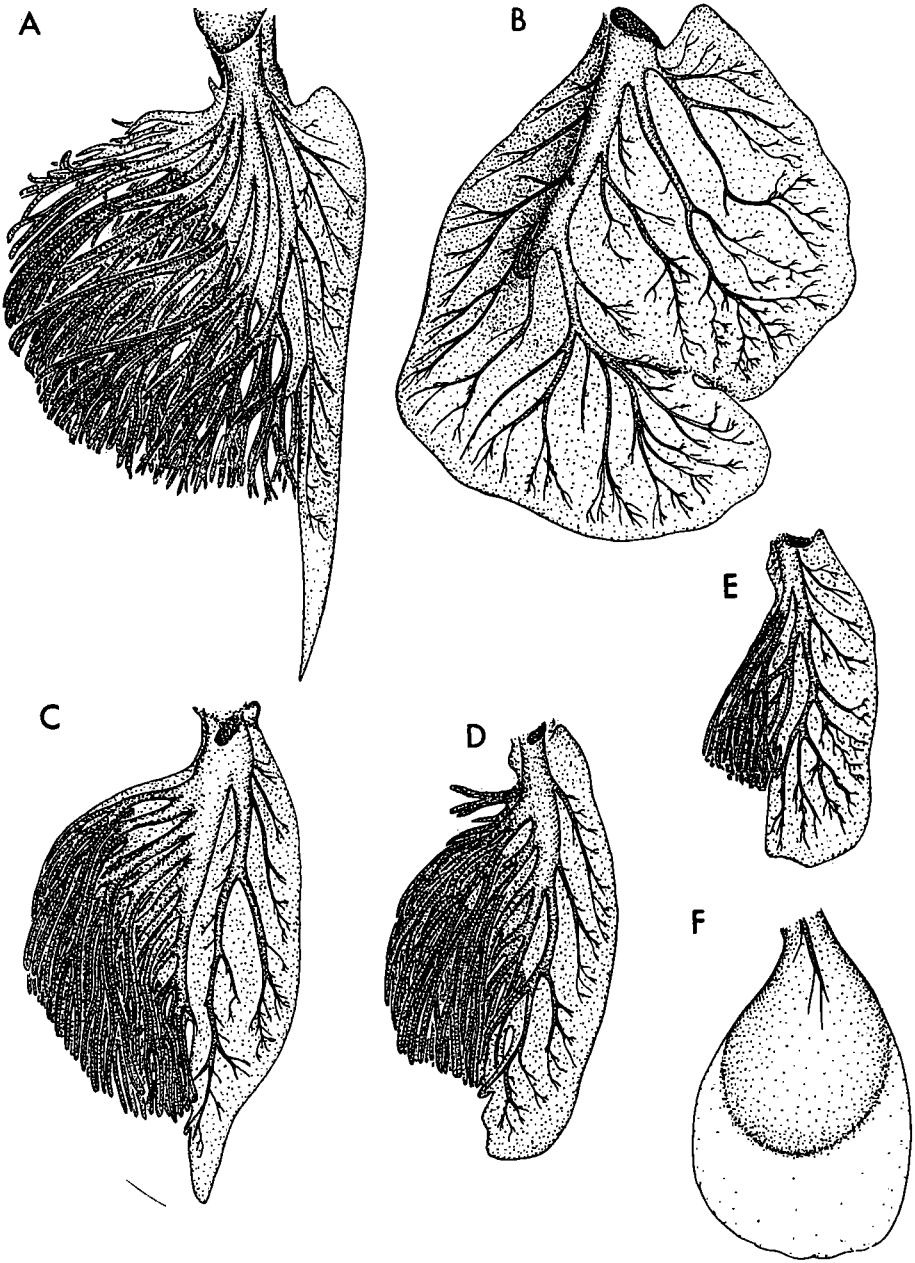

FIGURE 16.—Gills of mature nymph of *B. rogersi*: A) gill 1; B) gill 2; C) gill 3; D) gill 4; E) gill 5; F) gill 6.

cles at posterior margin; basal 1/2 of pyramidal structure of tergum 6 blackish, dorsal surface pale; terga 7-9 light brown except margins smoky-brown; pyramidal structure of tergum 6 well developed with the posterior face subequal to the greatest

length of tergum 7; a prominent, continuous, dark brown, median line on terga 7-10, interrupted posteriorly on each tergum; anterior margins of terga 7-9 with a pair of dark-brown, transverse lines; mid-dorsum elevations of terga 7-9 pale, keel-shaped, approximately equal to 1/2 the length of the respective terga; lateral borders of terga 6-9 crenulated; crenulation weakest at tergum 6; posterolateral corners of terga 6-9 produced into spines as in Figure 14 D; abdomen of males more flattened than those of the females. Sterna light brown with numerous black tubercles; lateral margins of sterna 1-5 dark brown; a small network of black stipplings near anterior and posterior margins of sterna 1-8; prominent black macula near anterolateral corners of sterna 6-9; posterior border of sterna 6-9 weakly crenulated; subanal plate deeply cleft apically. Caudal filaments (Fig. 14 D): cerci light brown, darker at base; basal 2/3 of median filament reddish-brown; remainder of filament brown; posterior 2/3 of caudal filaments with long brownish hair.

The twelfth instar molted after 17-21 days, averaging 17.6 days.

GROWTH AND DEVELOPMENT

We reared the first three nymphal instars of *Baetisca rogersi* from eggs hatched in the laboratory. Instars four through twelve came from young nymphs collected in the field and reared individually in the laboratory. The fourth instar identification was based on body length, head width, and degree of development of the thoracic notal shield.

Although addmittedly little research has been completed on other species, this represents the lowest total number of instars reported in the Ephemeroptera. Ide (1935b) estimated a total of 30-45 instars for *Stenonema canadense* (Walker) and about 30 instars for *Ephemera simulans* Walker. Murphy (1922), rearing small groups from eggs, found 27 stadia (apparently all nymphal instars) in *Baetis posticatus* (Say). Rawlinson (1939) reared and classified 17 developmental stages in *Ecdyonurus venosus* (Fabricius). These morphological stages did not correspond to instars in this species but occurred independently at different instars. However, from information on the Palmen organ of two young (6 mm) nymphs, Rawlinson stated that the minimum possible number of molts was 16. Degrange (1959) reared 43 nymphs of *Cloeon simile* Eaton from egg to imago; the number of molts (including the subimaginal molt) varied from 21-30. Degrange was also able to correlate successfully the number of layers in the Palmen organ with the number of molts. Finally, applying Dyar's rule to a laboratory population, Froehlich (1969) calculated a total of 15-16 nymphal instars for *Caenis cuniana* Froehlich.

The data indicate a total of 12 nymphal instars in *B. rogersi*. No alternate method of estimating the number was made. Dyar's rule is a geometric growth ratio; its calculation requires a large population reared under constant conditions. Lacking necessary technical equipment, we made no attempt to dissect the Palmen organ. An undiscovered instar might conceivably exist between the third and fourth instars. Also

TABLE 2.—DURATION OF NYMPHAL INSTARS OF *Baetisca rogersi* UNDER LABORATORY CONDITIONS.

Instal	No.	Minimum–maximum no. days duration	Average duration
I	37	2–4	3.2
II	22	3–5	4.2
III	2	died after 2 days	?
IV	4	collected in field—2–5 days	?
V	4	10–12	10.7
VI	4	11–14	12.5
VII	5	12–15	13.2
VIII	5	12–16	14.8
IX	6	14–16	15.2
X	6	14–18	16.8
XI	8	16–19	17.6
XII	7	17–21	19.1

nymphal growth under natural conditions, being much more prolonged than laboratory growth, could involve additional instars; however this appears unlikely in *B. rogersi*. Further, as Degrange (1959) conclusively demonstrated, instars from eggs of one female reared under identical conditions can have different numbers of molts. Nevertheless, we shall refer to 12 instars of *B. rogersi* as they are distinct and recognizable.

Table 2 shows the minimum, maximum, and average durations of nymphal instars reared in the laboratory, except for the third and fourth instar nymphs. The duration of the later instars is longer than that of the earlier instars; average duration increased progressively from the first to second and from the fifth to twelfth instars. Although there was no record of the duration of the third and fourth instars, we estimate that each of these instars require no more than 10 days. Therefore the approximate length of nymphal development of *B. rogersi* in the laboratory is about 4 months.

We collected nymphs in the study area from September through early July. Collecting continued through the summer unsuccessfully. The earliest record of young nymphs was 20 September 1968 and the nymphs were in the fourth instar based on size and external features. The eggs probably hatched in early September. In the laboratory incubation time of the eggs ranged from 20-31 days averaging 23.8 days, and hatching continued for 7-17 days. If the same length of time is required to hatch eggs in the field, then those laid in March should have hatched in April and May. However diapause and dormancy at high and low temperatures have been demonstrated in Ephemeroptera eggs (Bohle 1968). Although no experimental work was done with *B. rogersi*, we

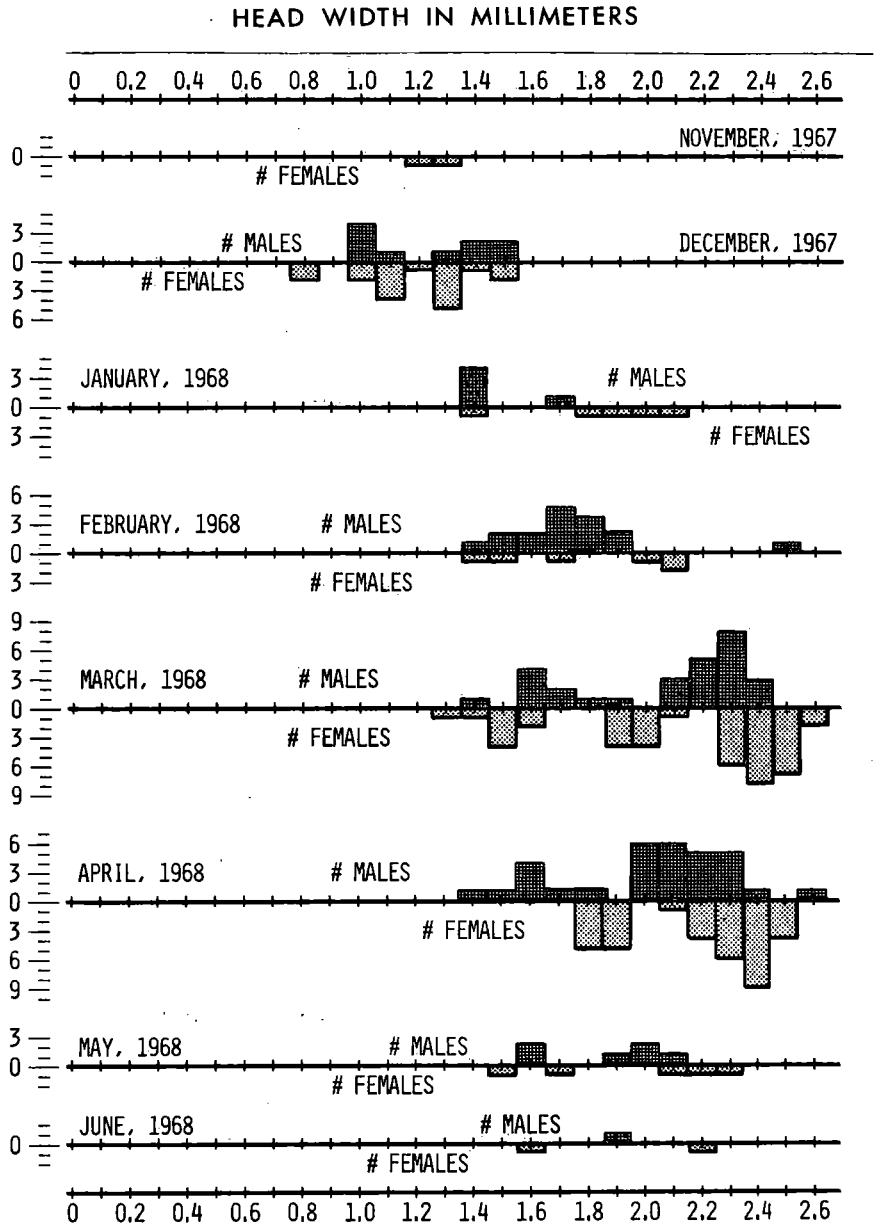

FIGURE 17.—Size-frequency distribution of *B. rogersi* nymphs collected at Rocky Comfort Creek, 1967-1968.

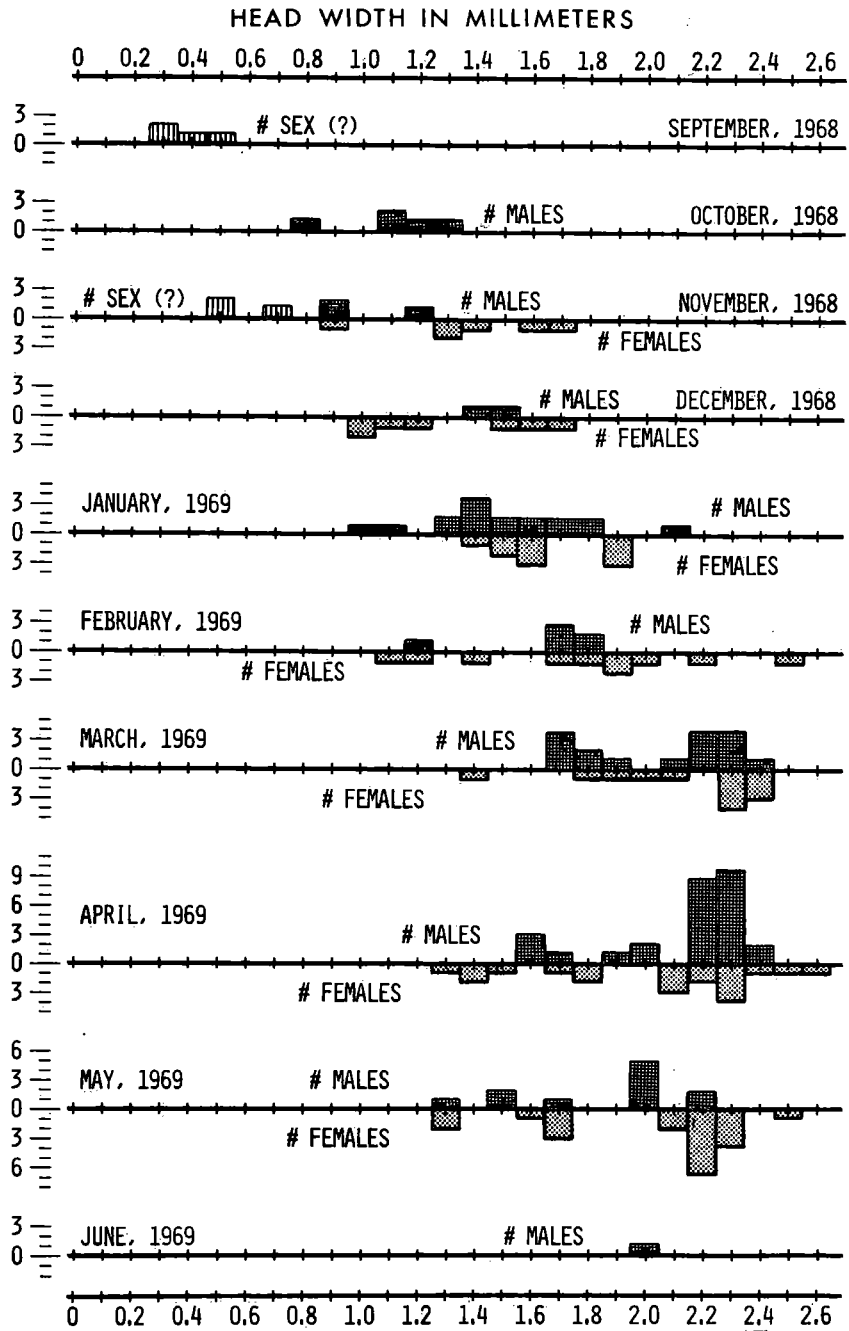

FIGURE 18.—Size-frequency distribution of *B. rogersi* nymphs collected at Rocky Comfort Creek, 1968-1969.

TABLE 3.—SEASONAL DISTRIBUTION, EXPRESSED BY NUMBER OF NYMPHAL INSTARS COLLECTED PER MONTH, OF *Baetisca rogersi* IN ROCKY COMFORT CREEK, 1967–68.

Date	1967				1968							
Instar	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
I									142[1]	76[1]	10[1]	
II									19[1]	3[1]		
III										1[1]		
IV												
V				1								
VI				4	2							
VII			2	13	1	1	1					
VIII				8	10	4	7	1	1			
IX					5	12	13	9	3	1		
X					1	4	5	10	1			
XI					1	4	1	9	5	1		
XII						1	41	43	2	1		

[1]Laboratory reared specimens only which may not reflect field conditions.

surmise that most eggs did not hatch until temperatures cooled in the fall, and the hatching continued for more than 17 days. The variability and fluctuation of natural stream conditions should prolong hatching beyond those times recorded in the laboratory. Ide (1935a), noting that eggs of *Stenonema canadense* hatched over a period of 6 weeks, assumed that different incubation times for the eggs are genetically based.

Nymphs that did hatch in April were probably killed by the high temperatures and low oxygen content of the water (Figs. 7, 8). Newly hatched nymphs reared in the laboratory at 22.2°-23.9° C died after one molt. When water temperatures were lowered to 18.9°-21.1° C and other variables remained the same, the nymphs lived longer, an indication that temperature is important in survival of early instar nymphs. Ide (1935a) believed that eggs of certain mayfly species remain dormant during summer and those that hatch early are killed by high temperature. Also the low oxygen content of the stream water in summer (Fig. 8) is probably detrimental to the early instar nymphs.

Size measurements of nymphs included total body length, exclusive of caudal filaments, and head width. From these measurements total range of nymphal body length was 0.40 mm for the first instar to 8.80 mm (male) and 9.90 mm (female) for the twelfth instar. Head width ranged from 0.09 mm for the first instar to 2.50 (male) and 2.60 (female) for the twelfth instar.

Figures 17 and 18 give size-frequency distributions of *B. rogersi*

TABLE 4.—SEASONAL DISTRIBUTION, EXPRESSED BY NYMPHAL INSTARS COLLECTED PER MONTH, OF *Baetisca rogersi* IN ROCKY COMFORT CREEK, 1968–69.

Date	1968				1969							
Instar	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
I							8[1]	154[1]	43[1]	47[1]		
II								30[1]	11	2[1]		
III									1[1]			
IV	4		2									
V			1	2								
VI		1	4	2	1							
VII		4	3	2	4	4		1	3			
VIII			1	5	13	1	1	5	2			
IX			1	2	6	4	4	5	5			
X					3	3	7	3				
XI					3	2	6	6	2	1		
XII						1	12	115[2]	57[2]	21[2]	2[2]	

[1]Laboratory reared specimens only which may not reflect field conditions.
[2]Total includes nymphal exuvia of subimagos observed emerging in field.

based on head width of nymphs collected in the field. We used head width because we found it to be the least variable index of growth. For the 1968-1969 season, nymphs collected in September had head widths of 0.30-0.50 mm. Nymphs collected in October had head widths of 0.80-1.30 mm, in November 0.40-1.70 mm, in December 1.00-1.50 mm, reaching in March and April widths of 2.50-2.60 mm (Fig. 18). No increase in maximum width occurred after April. Results for the 1967-1968 season were similar (Fig. 17) as were the seasonal distributions of the instars (Tables 3 and 4).

Low temperatures probably accounted for the slow growth of the nymphs during December. Cold temperatures were first recorded in November (Fig. 7). They dropped to a low of 5° C in December and January and apparently reduced nymphal feeding, slowing nymphal growth. As the water warmed in late January (Fig. 7), the nymphs grew rapidly. Many authors have given similar results. In a study of the factors influencing the life histories of some species of mayflies in Alberta, Hartland-Rowe (1964) reported that no growth occurred in nymphs of *Epeorus longimanus* (Eaton), *Ephemerella inermis* Eaton, and *E. lapidula* McDunnough during the period when the stream temperature was 0° C. Harker (1952) reported that the growth rate of *Ecdyonurus torrentis* Kimmins dropped from November to February when the temperature was below 6° C. Similarly, Moon (1939) found that no growth took place in winter for nymphs of *Caenis horaria* (L.). In fact reduction in and absence of overwinter growth are generally

TABLE 5.—SEASONAL VARIATION IN SIZE OF LAST INSTAR NYMPHS OF *Baetisca rogersi* COLLECTED IN ROCKY COMFORT CREEK.

Date Collected	Males				Females			
	Body length mm		Head width mm		Body length mm		Head width mm	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
1968								
March	7.30–8.90	8.07	2.10–2.40	2.26	7.60–9.90	9.05	2.20–2.60	2.42
April	7.20–8.40	7.68	2.10–2.40	2.17	7.40–9.60	8.63	2.10–2.50	2.32
May	6.70–8.00	7.36	1.90–2.30	2.13	7.40–8.90	8.00	2.10–2.30	2.10
June[1]	7.20	7.20	2.10	2.10				
1969								
March	7.90–8.60	8.31	2.20–2.40	2.30	8.50–9.30	8.90	2.30–2.50	2.40
April	6.90–8.60	8.00	2.00–2.40	2.26	8.20–9.60	8.81	2.10–2.40	2.35
May	6.40–8.00	7.37	2.00–2.20	2.12	7.40–9.00	8.34	2.10–2.50	2.47
June[1]	7.30	7.30	2.00	2.00				

[1]Only one specimen.

recognized phenomena, which Landa (1968) classifies as A1 (reduced growth) and A3 (no growth) in his characterization of developmental cycles of European Ephemeroptera.

We classified nymphs from the monthly field collections to instar by comparing them morphologically to those known nymphal instars reared in the laboratory (Tables 3 and 4). The size range of instars from the field varied more than those from the laboratory. Nymphs from the field were generally larger in body size, reaching a maximum body length of 8.9 mm (males) and 9.9 mm (females) compared to 8.0 mm (males) and 8.6 mm (females) for those reared in the laboratory. Also, the range of body size of the different instars from the monthly collections overlapped. For example the body length of eleventh instar males ranged from 6.6-8.1 mm compared to 6.8-8.9 mm for twelfth instar males; the same phenomenon occurred in females. A possible explanation for size overlap is that larger nymphs may be physiologically younger than smaller nymphs (Clifford 1970), or nymphs of the same stage may exhibit different growth rates as Hunt (1953) found in *Hexagenia limbata* (Guerin).

The average size of last instar nymphs collected in May and June was smaller than that of last instars collected in March and April (Table 5). Similar findings were reported by Gledhill (1959) for *Ameletus inopinatus* Eaton, Minshall (1967) for *Epeorus pleuralis* (Banks), and Clifford (1970) for *Leptophlebia cupida* (Say). Following these authors, the larger *B. rogersi* nymphs collected in March would be those that overwintered half-grown; last instar nymphs in May and June would

TABLE 6.—SUBSTRATUM PREFERENCES OF THE NYMPHS OF *Baetisca rogersi*.

Trial	Type of bottom	12 hr.	36 hr.	48 hr.	Total No.	Total %
I	A (stony)	7	13	12	32	71.1
	B (sandy)	1	1	2	4	8.9
	C (leaf-litter)	7	1	1	9	20.0
II	A (stony)	12	14	13	39	86.7
	B (sandy)	0	1	1	2	4.4
	C (leaf-litter)	3	0	1	4	8.9
III	A (stony)	10	13	15	38	84.4
	B (Sandy)	2	1	0	3	6.7
	C (leaf-litter)	3	1	0	4	8.9
Total	A (stony)	29	40	40	109	80.7
	B (sandy)	3	3	3	9	6.7
	C (leaf-litter)	13	2	2	17	12.6

be those that achieved most of their growth in spring, thus maturing faster. Favorable water temperatures (Fig. 7) an increased supply of diatoms (Table 8), and increased photoperiod are probably the major factors accelerating nymphal growth in spring (Thibault 1971).

In summary, although laboratory data show that *B. rogersi* could support two or more generations each year, only one occurs in north Florida. Thus unknown factors prolong the life cycle, delaying hatching or young nymph development until fall and slowing nymphal overwinter growth. We agree with the conclusions of other workers, most recently Thibault (1971), that while temperature is not the only factor regulating the length of the life cycle, it is among the most important. For *B. rogersi*, temperature (Fig. 7), oxygen (Fig. 8), and food supply (Table 8) appear significant; we did not investigate photoperiod.

HABITAT AND HABITS

Mature *Baetisca rogersi* nymphs in Rocky Comfort Creek were typical members of a lithophilous association, living in the exposed, stony substratum of the sampling station. Younger nymphs, the fourth through seventh instars, lived only in areas with a thick growth of filamentous algae and water moss (*Spirogyra* sp. and *Leptodictyum riparium*). Also as nymphs approached emergence they moved to quiet, shallow sections of the stream. This move to a quiet area may be associated with the search for objects or places to leave the stream and emerge.

The habitat of the nymphs in Bear Creek was similar. Most early

TABLE 7.—INFLUENCE OF LIGHT ON SUBSTRATUM PREFERENCES OF NYMPHS OF *Baetisca Rogersi*.

Trial	Type of bottom	12 hours		36 hours		48 hours		Total	
		Light	Dark	Light	Dark	Light	Dark	Light	Dark
I	A (stony)		4		3	15		15	7
	B (sandy)		0	11			0	11	0
	C (leaf-litter)	11			1		0	11	1
II	A (stony)		5		5	15		15	10
	B (sandy)		0	10			0	10	0
	C (leaf-litter)	10			0		0	10	0
III	A (stony)	14			3		2	14	5
	B (sandy)		0	12			0	12	0
	C (leaf-litter)		1		0	13		13	1
Totals	No.	35	10	33	12	43	2	111	24
	%	77.8	22.2	73.3	26.7	95.5	4.5	82.2	17.8

instar nymphs were collected in a thick mat of *L. riparium* along the submerged concrete wall of the bridge. Larger or older individuals frequented the underside of submerged logs or partially buried themselves in the sand along the shallow edges of the stream.

In the laboratory eighth through twelfth instar nymphs preferred a stony substratum, but when this was not provided they partially buried themselves in the sand or firmly attached themselves along the corners of the aquarium. Nymphs also congregated on a plastic screen stretched along the inside of the aquarium.

In a laboratory experimental study on habitat preference, light and stony substratum significantly influenced the distribution of the nymphs. We conducted two experiments as explained in *Methods*. In one experiment a tray with three substrata was exposed to light. Combined results of three trials showed an average of 80.7% of nymphs studied were found in Section A with stony bottom, 6.7% in Section B with sandy bottom, and 12.6% in Section C with a substratum composed of leaf litter (Table 6, Fig. 19 A). In trial I, 71.1% of the nymphs moved to Section A, 86.7% in trial II, and 84.4% in trial III.

In a further experiment we exposed one section of the tray to light while the other two sections were covered. Fifteen nymphs were used in each of three trials. Results are shown in Table 7 and Figure 19 B. Section C (leaf litter) was lighted while Section A (stones) and Section B (sand) were covered. After 12 hours 11 (73.3%) of 15 nymphs occupied Section C (light, leaf litter), 4 (26.7%) Section A (dark, stones), and none Section B (dark, sand). Then Section B was lighted.

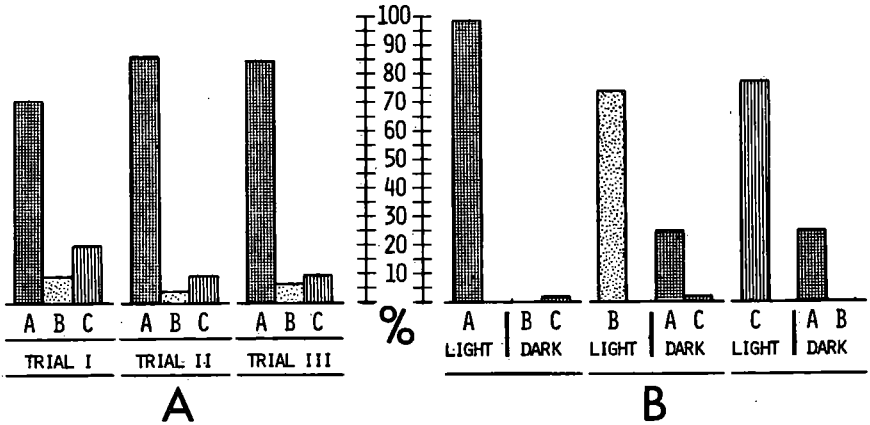

FIGURE 19.—Importance of substratum and light on habitat preference of *B. rogersi* nymphs: A shows %of nymphs frequenting a substrate when all are in light; B shows % of nymphs on each substrate when one substrate is in light and the others are dark. Substrates are stony (A), sandy (B), or with leaf-litter (C).

Results show 11 (73.3%) nymphs were found in Section B, 3 (20%) in Section A (dark, stones), and 1 (6.7%) in Section C (dark, leaf-litter). When Section A (stones) was lighted, all of the nymphs (100%) moved to this section. Similar results were obtained in trials II and III. A majority of the nymphs confined themselves to the lighted division of the tray regardless of the type of substratum. Light appears to be more significant than substratum in influencing the habitat choice of *B. rogersi* nymphs. The fact that a few nymphs remained in the stony bottom portion of the tray even when dark suggests that the nature of the stream bed and light combined influence the distribution of nymphs in the stream. Hughes (1966b) reported a number of mayfly species that exhibit the same light response but offered no explanation as to the mechanism involved.

Current also limited the distribution of *B. rogersi* nymphs in the stream. Nymphs were usually in running water. Those in quiet portions of the stream were last instar nymphs and their presence was probably associated with their search for objects or places to emerge.

The nymphs of *B. rogersi* are morphologically adapted for life in flowing water. Their tarsal claws (Fig. 15 H) are heavily sclerotized, curved, and sharply pointed, enabling them to hold firmly to objects in the substratum. The thoracic notal shield with its dorsal elevations and dorsal and lateral spines apparently helps decrease resistance to current. Hora (1930) suggested that spines on blepharocerid larvae are developed as a means of diminishing resistance to strong current; the spines create a layer of calm water against the body of the larva.

Nymphs were not active during the day. They usually stayed under rocks, or partially buried in the sand. When at rest, the last three abdominal segments are bent dorsally with the caudal filaments over the body. In the laboratory, we sometimes saw the nymphs wave their caudal filaments in a steady up and down motion. This beating probably aids respiration by creating a water current. Other possible reasons for such movements are: they help the nymphs maintain balance and position, or they clean silt and debris from the nymphs' bodies.

Newly collected nymphs brought to the laboratory were positively phototactic. In an experimental study on the dorsal light response, the nymphs exhibited "somersaulting" behavior. "Somersaulting" is a term used to describe the light-orientation response displayed by many aquatic invertebrates. When a light is directed into a container from the side, nymphs swim with the dorsal surface to their body towards the light and the ventral surface away. After passing the light they return to their normal orientation. This behavior resembles a loop or a "somersault." In a further experiment, we covered an aquarium with black paper, leaving only one small spot of light. Nymphs crawled to and congregated at the light. When this light spot was moved under the aquarium, nymphs tried to dig down, head first, to it. Evidently the position of the light source has a very marked influence on the maintenance of the primary dorsoventral orientation of the nymphs. Hughes (1966a) postulated that the dorsal light response of *Baetis harrisoni* Barnard is initiated by the ocelli and maintained by the compound eyes. He further stated that the ocelli are only transparent to light and therefore only a very small response is elicited. Whether the same explanation could be offered for the nymphs of *B. rogersi* needs further investigation.

Nymphs remained motionless when touched. As their coloration closely resembles their habitat, such behavior has apparent survival value.

The swimming activities of various species of *Baetisca* nymphs have been described by Walsh (1864), Traver (1931), and Berner (1950). Our observations of the movement of *B. rogersi* nymphs agree with those given by Berner (1950). Nymphs swim by the vigorous and rapid undulation of the last three abdominal segments including the caudal filaments. The legs are drawn under the body with the prothoracic legs oriented forward and with the tibiae and tarsi at right angles to the femora. The mesothoracic and metathoracic legs are directed posteriorly. As the nymphs come to rest the legs spread and seize any available supporting object. The legs are not used in the actual process of swimming. The force that initiates swimming apparently comes from the last three abdominal segments. These are bent upward with the caudal

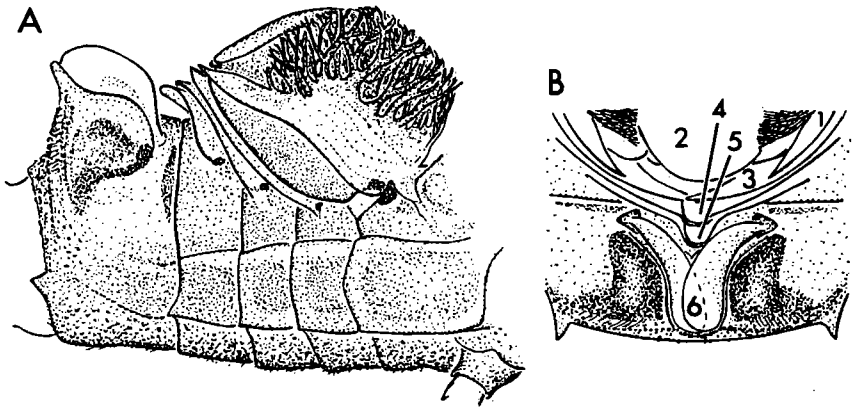

FIGURE 20.—Gill position of mature *B. rogersi* nymph: A) lateral view; B) dorsal view of gill apices and abdominal segments 5–6.

filaments held over the body. A sudden return to their normal position followed immediately by continued upward and downward beats provides momentum. Nymphs often float for a period of time before swimming movements begin. After the nymphs leave the substratum they swim vigorously for a while and then dive downward to reach the bottom quickly.

To investigate Berner's (1940) theory lateral spines of the thoracic notal shield of *Baetisca* act as balancers, we removed these spines. Without them the nymphs could not balance themselves, or could just barely maintain a normal position for a short time before turning over. Furthermore, the nymphs could not maintain direction. Instead of swimming forward as they normally do, a zigzag pattern occurred and the nymphs were limited to a short distance. Evidently the lateral spines do stabilize the nymphs in the water as Berner suggested. The spines perform a similar function in *B. rogersi*'s alternate habitat, stabilizing the nymphs in moving sand. Spines also reduce current resistance, as previously discussed.

The abdominal gills of *B. rogersi* are completely enclosed under the thoracic notal shield, apparently for protective purposes. The gills are used for respiration, a process we studied in living nymphs. The notal shield raised and lowered in a rhythmic fashion enabling water to circulate inside the gill chamber. Water flowed into the cavity through a space between the lateral edges of the thorax. Inflow of water occurred during the upward stroke of the notal shield; when the notal shield returned to its normal position, water flowed out from the cavity. We removed the thoracic notal shield to study gill movements (Fig. 20 A). The gills exhibited simple upward and downward strokes. The

TABLE 8.—RELATIVE ABUNDANCE OF GUT CONTENTS OF NYMPHS OF *Baetisca rogersi* COLLECTED IN ROCKY COMFORT CREEK, NOVEMBER 1968 TO MAY 1969.

Month	Total no. of items counted	% Detritus	% Diatoms	% Filamentous algae	% Mineral particles	% Arthropod remains
Nov.	312	51.28	17.63	2.24	28.85	0.00
Dec.	308	51.63	13.96	2.27	32.14	0.00
Jan.	198	59.09	10.61	1.01	29.29	0.00
Feb.	277	44.77	33.21	11.19	10.83	0.00
Mar.	378	46.56	36.24	0.53	15.61	1.06
Apr.	423	55.32	37.35	0.71	6.62	0.00
May	401	53.37	17.95	0.25	28.43	0.00

upward motion was more or less directed sideward with the downward stroke a simple return to normal position. As water flows from the cavity, the small plate-like gills of the sixth abdominal segment snugly join together and form a tube that fits into the circular space between the posterior elevation of the notal shield and the concave dorsal surface of tergum 6 (Fig. 20). The sixth abdominal gills serve as a channel for the discharge of water from the cavity.

The nymphs of *B. rogersi* are detritivorous. Examination of 21 nymphs revealed the dominant gut components as detritus, diatoms, mineral particles, and a few fragments of filamentous algae (Table 8). Identified diatoms were *Navicula* sp., *Surirella* sp., *Nitzschia* sp., *Meridion* sp., *Pinnularia* sp., *Fragilaria* sp., and *Gomphonema* sp. One desmid, *Micrasterias* sp., was also found. Among the recognizable filamentous algae were *Spirogyra* sp., *Cladophora* sp., and *Oedogonium* sp. We also found a few fragments of arthropod remains in one specimen, but these were probably ingested accidentally. Although alimentary tracts of both large and small nymphs collected throughout the season were examined, no significant differences were discernible in the composition of materials eaten by the various instars. We did note an increase in abundance of diatoms among dissected nymphs collected in February, March, and April, when a thick population of diatoms covered the rocks in the stream. Nymphs of many mayfly species feed on diatoms, algae, and organic debris as reported most recently by Minshall (1967) and Coffman, Cummins, and Wuycheck (1971).

The nymphs feed at night. In the laboratory they browsed on the surface of rocks and crawled back and forth on the substratum apparently feeding. Sometimes they bit off pieces of water moss. While feeding the nymphs alternately raked the substratum towards the mouthparts with the tibiae and tarsi of the prothoracic legs. The nymphs also placed their prothoracic legs between the mouthparts apparently re-

moving food particles. Attempts to study the movements of the mouthparts while feeding were unsuccessful.

Many of the ninth through twelfth instars rested on the plastic screen in pairs, one on top of the other. At first we thought the nymphs were copulating because of their position and, in each case, the pair consisted of a male and female. Careful observations, however, proved our assumption incorrect. Some of the paired nymphs were dissected and their reproductive organs examined under the microscope. The female reproductive organs were not well developed and male sperm were immature. Twelfth instar females did have mature ovaries, but extracted eggs did not hatch. The significance of this paired behavior remains unknown.

In the laboratory, nymphs of the twelfth instar crawled up to the surface of the water and attached themselves on the plastic screen along the edge of the aquarium with the dorsum of the head exposed above the water surface. This behavior occurred only a few minutes prior to emergence.

Associated Organisms

We preserved and identified all macro-organisms collected with *Baetisca rogersi* during the weekly samplings. These collections reveal not only the diversity of the faunal composition, but also offer a better understanding of the ecological community in which *B. rogersi* lives. Most of the organisms associated with it were arthropods, mainly insects. A list follows.

		Crustacea
Decapoda	Astacidae	*Procambarus spiculifer* (Le Conte)
Isopoda	Asellidae	*Asellus* sp.
		Arachnoidea
Hydracarina	Athienemanniidae	*Krendowskia* sp.
		Insecta
Ephemeroptera	Siphlonuridae	*Isonychia* sp. A of Berner *Isonychia* sp. B of Berner
	Baetidae	*Baetis spiethi* Berner *B. spinosus* McDunnough *B. intercalaris* McDunnough
	Heptageniidae	*Stenonema exiguum* Traver *S. smithae* Traver *Stenonema* sp.
	Metretopodidae	*Siphloplecton speciosum* Traver

	Leptophlebiidae	*Leptophlebia intermedia* (Traver) *Leptophlebia* sp. *Paraleptophlebia volitans* (McDunnough)
	Ephemerellidae	*Ephemerella* (s.s.) *choctawhatchee* Berner *E.* (*Dannella*) *simplex* McDunnough *E.* (*Dannella*) sp. *E.* (*Eurylophella*) *trilineata* Berner
	Tricorythidae	*Tricorythodes albilineatus* Berner
	Neoephemeridae	*Neoephemera youngi* Berner
	Caenidae	*Brachycercus maculatus* Berner *Brachycercus* sp. *Caenis hilaris* (Say) *C. diminuta* Walker
	Baetiscidae	*Baetisca obesa* (Say)
Odonata	Aeschnidae	*Boyeria vinosa* (Say)
	Gomphidae	*Gomphus* (s.s.) *minutus* Rambur *G.* (*Stylurus*) *ivae* Williamson *Progomphus obscurus* (Rambur)
	Libellulidae	*Macromia* sp.
	Calopterygidae	*Calopteryx maculata* (Beauvois)
	Coenagrionidae	*Argia moesta* (Hagen)
Plecoptera	Pteronarcidae	*Pteronarcys nobilis* Hagen
	Nemouridae	*Taeniopteryx maura* (Pictet) *Taeniopteryx* sp.
	Perlidae	*Acroneuria* sp. *Neoperla clymene* (Newman) *Neoperla* sp. *Perlinella drymo* (Newman) *Perlinella* sp. *Perlesta placida* (Hagen) *Perlesta* sp. *Phaganosphora capitata* (Pictet)
Megaloptera	Sialidae	*Sialis* sp.
	Corydalidae	*Chauliodes rastricornis* (Rambur) *Nigronia serricornis* (Say)
Coleoptera	Haliplidae	*Haliplus* sp.
	Gyrinidae	*Dineutes* sp.
	Elmidae	*Stenelmis convexula* Sanderson *Macronychus glabratus* Say
Trichoptera	Psychomyiidae	*Nytiophylax* sp. *Phylocentropus placidus* (Banks)
	Hydropsychidae	*Hydropsyche orris* Ross *Cheumatopsyche pinaca* Ross

	Leptoceridae	*Athripsodes angustus* (Banks) *A. cancellatus* (Betten) *A. nephus* Ross *A. transversus* (Hagen) *Oecetis persimilis* (Banks)
Diptera	Tipulidae	*Tipula abdominalis* (Say) *T.* (*Yamatotipula*) *caloptera* Loew *T.* (*Yamatotipula*) sp.
	Chironomidae	*Ablabesmyia mallochi* (Walley) *Cricotopus bicinctus* (Meigen) *Cricotopus* sp. *Metriocnemus lundbeckii* Johannsen *Polypedilum* (s.s.) sp. *Procladius culiciformis* (L). *Tanytarsus* sp.
	Simuliidae	*Simulium* sp.

In addition to the arthropods, several species of fish lived near the *B. rogersi* nymphs habitat. Species of fish collected were pirateperch (*Aphredoderus sayanus*), brown darter (*Etheostoma edwini*), gulf darter (*E. swaini*), mosquitofish (*Gambusia affinis*), yellowbelly sunfish (*Lepomis auritus*), lowland shiner, (*Notropis cummingsae*), sailfin shiner (*N. hypselopterus*), speckled madtom (*Noturus leptocanthus*), blackbanded darter (*Percina nigrofasciata*). A mole salamander, *Ambystoma* sp., was also collected in the study area.

Mayfly nymphs have long been known as an important food of freshwater fish. The gut contents of fish examined from the study areas contained undigested leg segments and mandibles of mayflies, but all were too decomposed to be identified positively to species.

Figure 21 gaves a list of mayfly species associated with nymphs of *B. rogersi* indicating the seasonal succession of the mayfly fauna in the habitat.

Twice we found pupae of *Simulium* sp. attached to the median posterior half of the dorsal surface of the thoracic notal shield of *B. rogersi*, but larvae so attached we never found. The *Simulium* may have mistaken quiet *B. rogersi* nymphs for stones. The small percentage incidence ($< 1\%$) of attached pupae suggests only a fortuitous association.

The Subimagos

External Morphology

Male Subimagos (live specimens) (Fig. 2): Body length 6.3-8.2 mm; fore wings 8.0-9.2 mm; caudal filaments 5.3-6.9 mm. Head: grayish-brown, darker at posterior margin of vertex; dorsal surface of genae near base of compound eyes grayish-yellow; frons grayish except adjoining areas surrounding the ocelli brownish. Antennae: pale, basal segment washed with brown; antennal socket including basal segment grayish-brown; remainder of segments pale. Compound eyes grayish-yellow. Ocelli pale yellow, reddish-brown at base. Thorax: pronotum narrow, grayish-brown except median line pale. Mesonotum grayish-brown, covered with fine black stipplings;

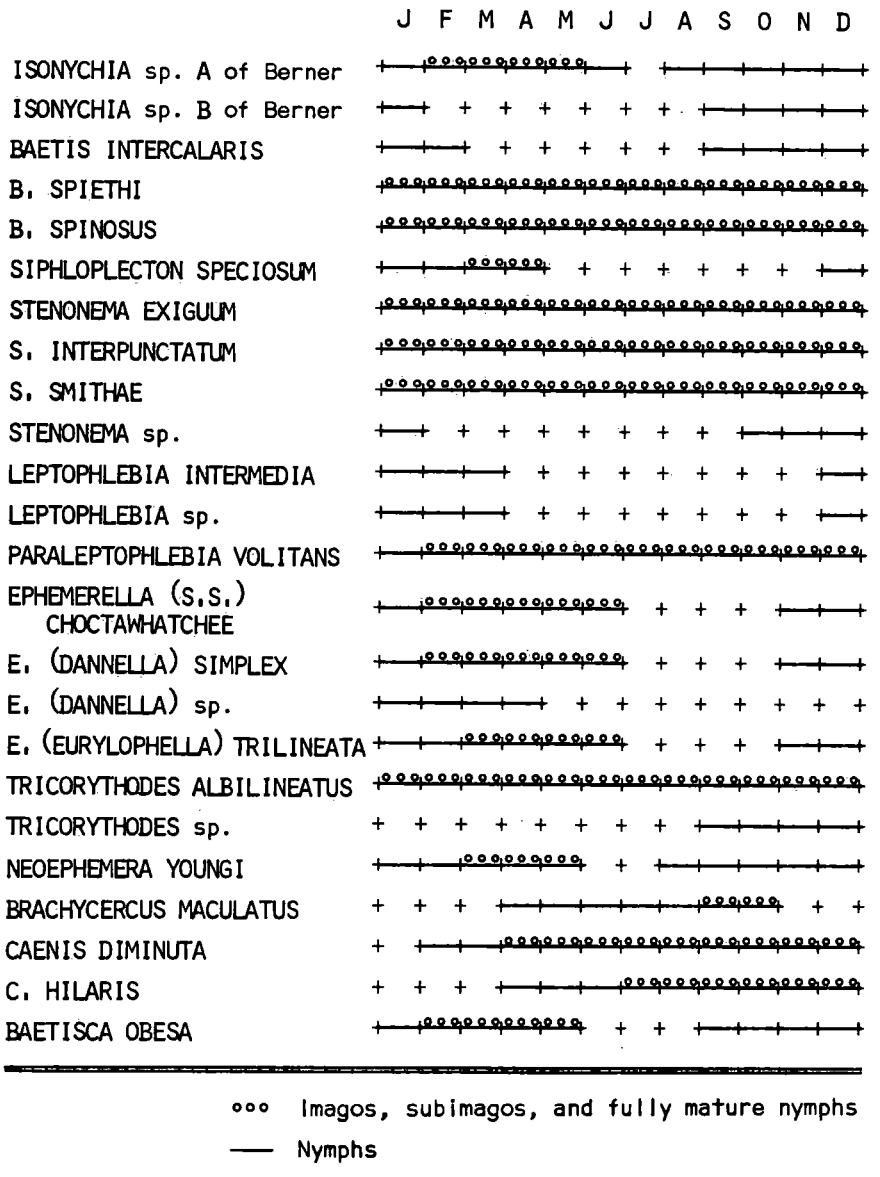

FIGURE 21.—Seasonal distribution of Ephemeroptera species associated with *B. rogersi* at Rocky Comfort Creek.

parapsidal furrows reddish-brown, anterior 1/3 of inner parapsidal furrows flexed inwardly towards median line to form an irregular M-shaped marking on mesonotum; median line of mesonotum pale, mesoscutellum saddle-shaped with a distinct macula near the anterolateral margin, mesoscutellum grayish-brown, darker at margins and blackish at posterolateral margins, posterior margin truncated. Metanotum grayish-

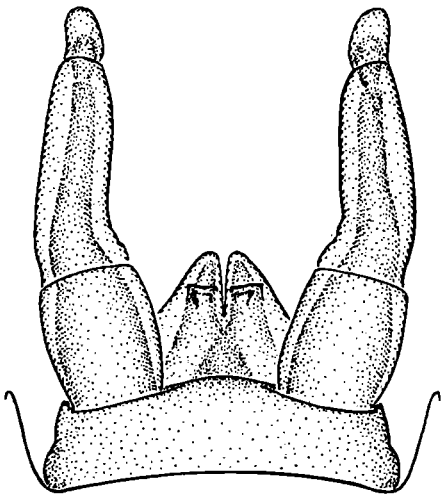

FIGURE 22.—Ventral view of male genitalia of *B. rogersi* subimago.

brown; posterior 1/2 of metanotum membranous, covering entirely abdominal segment 1. Pleural areas of pronotum dark grayish-brown; epimeron and episternum of mesothorax and metathorax including the axillary sclerites reddish-black, remainder of pleuron grayish. Prosternum grayish, submedian projections grayish-brown, and extend beyond posterior bases of fore coxae; mesosternum and metasternum grayish-yellow; ventral extensions of pleuro-trochantin near basisternum smoky brown. Furca of mesosternum and metasternum ringed with dark brown. Basisternum and metasternum covered with fine black stipplings. Legs: pale yellowish-brown except dorsal surface of coxae washed with dark grayish-brown; dorsal surface of each tarsal joint with a black transverse band at apex; dorsum of fore claws brown, venter pale; ratios of segments in male forelegs 1.62:1.00(0.80 mm):0.59:0.36:0.35:0.18:0.46; mesothoracic and metathoracic legs 1.41:1.00(0.81 mm):0.18:0.18:0.14:0.43. Wings (Fig. 2): longitudinal and cross veins of fore and hind wings grayish-brown, interrupted by whitish tranverse white spots throughout; posterior margins of fore wings bordered with short brownish hair; margin of hind wings bordered with short brownish hair; basal 2/3 of membrane of hind wings reddish-brown, remainder of membrane grayish-brown. Abdomen: tergum 1 pale, and entirely concealed under the membranous posterior 1/2 of metanotum of thorax; terga 2-3 short, reddish-brown, darker at lateral and posterior margins; prominent pale spiracular openings on terga 1-6; terga 6-9 light reddish-brown, darker at posterior and lateral margins on segments 6-8; prominent dorsal elevation on posterior 1/2 of tergum 6 heavily marked with fine black stipplings, prominent median line on terga 7-10; posterolateral spines of terga 6-8 weak, prominent on 9; anterior margin of terga 7-10 of most male subimagos covered with whitish granulations. Sterna 1-8 yellowish-gray, darker at lateral margins; sternum 9 pale; presence of fine black stipplings near anterior and posterior margins of sterna 1-8; lateral borders of sterna 1-5 produced into small pad-like structures overlapping each other; posterolateral margins of sterna 7-9 produced into projections, elongated into spines on sternum 9. Genitalia (Fig. 22): genital forceps and penes yellowish-white; forceps 3-segmented, segment 1 stout, shorter than segment 2; inner margin of segment 2 prominently curved near basal 1/3; apical segment small, and conical; penes triangular, subequal in length to the basal segment of forceps; basal 2/3 of penes fused. Caudal filaments: cerci yellowish-brown, pale

TABLE 9.—HOURLY EMERGENCE OF *Baetisca rogersi* SUBIMAGOS AT ROCKY COMFORT CREEK, 1969.

Date	Time of emergence						Stream water temp., C	Air temp., C	Relative humidity	Wind velocity, mph	Atmospheric condition
	8:30 AM–9:30 AM	9:31 AM–10:30 AM	10:31 AM–11:30 AM	11:31 AM–12:30 PM	12:31 PM–1:30 PM	1:31 PM–2:30 PM					
April 12	9	16	9	4	1	1	20°	24°	60%	2–3	partly cloudy
April 14	0	13	10	3	0	0	20°	26°	70%	5–8	clear
April 19	3	3	4	4	4	0	19°	24°	45%	3–5	clear
May 5	0	2	4	4	0	1	19°	26°	35%	2–4	clear
May 12	3	7	5	2	1	0	19°	28°	43%	3–5	clear
May 25	2	3	2	2	0	0	21°	31°	68%	5	partly cloudy
June 12	4	3	5	2	1	3	22°	32°	45%	2	cloudy
July 4	2	0	0	0	0	0	26°	33°	35%	3	clear
Total	23	47	39	21	7	5					

at apex; basal 2/3 of cerci with brown annulations at articulations; basal 1/2 of median filament reddish-brown, remainder hyaline.

Female Subimagos (live specimens): Body length 7.0-9.3 mm; fore wings 8.9-11.0 mm; caudal filaments 5.3-5.9 mm. Head: dark brown with black markings along median area of vertex; color of dorsal surface of genae near base of compound eyes as in male subimagos; frons dark brown except adjoining areas surrounding ocelli brownish. Compound eyes smaller than in male subimagos, grayish-yellow. Ocelli grayish-yellow, reddish-brown at base. Color and markings of antennae as in male subimagos. Thorax: color pattern as in male subimagos except inner parapsidal furrows and median notal suture darker; prosternal projection more separated and shorter than in male subimagos; mesosternum and metasternus covered with network of fine black stipplings markedly prominent on basisternum of mesothorax; mesothorax and metathorax including the posterior margin of abdominal segment 1 and 2 of some specimens covered with whitish granulations. Legs: color pattern as in male subimagos. Ratios of segments in fore legs 1.25:1.00(1:00 mm):0.21:0.21:0.12:0.34; mesothoracic and metathoracic legs 1.43:1.00(0.87 mm):0.17:0.17:0.13:0.41. Wings: color and markings of fore and hind wings as in male subimagos. Abdomen: color of tergum 1 as in male subimagos; terga 4-6 purplish-brown, almost black near posterior margin. Dorsal elevation of tergum 6 less pronounced than in male subimagos; color pattern of terga 7-10 as in male subimagos. Abdominal sterna covered with black reticulations, markedly prominent near anterior margins of 6-9. Posterior margin of sternum 9 concave forming a bifid subanal plate with a deep V-shaped median cleft (Fig. 25 C). Caudal filaments: color pattern of cerci as in male subimagos; basal 1/2 of median filament light reddish-brown, remainder pale.

EMERGENCE

The subimagos of *Baetisca rogersi* emerged from the stream from 8:30 AM to 2:30 PM as Table 9 shows. Most of the subimagos emerged

TABLE 10.—TIME REQUIRED FOR *Baetisca rogersi* SUBIMAGOS TO EMERGE FROM NYMPH.

Date	Time emergence commenced	Time emergence completed	Total no. of minutes
Laboratory:			
2.V.1968	3:10 PM	3:15 PM	5
2.V.1968	3:15 PM	3:21 PM	6
6.V.1968	2:33 PM	2:41 PM	8
12.V.1968	1:54 PM	1:58 PM	4
13.V.1968	1:40 PM	1:48 PM	8
19.V.1968	1:14 PM	1:20 PM	6
20.IV.1969	11:50 AM	12:00 PM	10
Field:			
11.IV.1969	10:50 AM	10:55 AM	5
14.IV.1969	10:33 AM	10:41 AM	8
14.IV.1969	11:55 AM	12:01 PM	6
19.IV.1969	10:28 AM	10:35 AM	7
			Average = 6.63

before noon with the emergence peak between 8:30 AM and 10:30 AM. Table 9 also shows a general decrease in the number of emerging subimagos toward the end of the emergence season.

Subimagos in the laboratory emerged from 10:00 AM to 8:30 PM, a few hours later than in the field. In 1968 the earliest emergence time was 10:00 AM and the latest 7:50 PM, whereas in 1969 times ranged from 11:00 AM to 8:30 PM. For both years the peak time of laboratory emergence occurred between 12:00 PM and 3:00 PM.

B. rogersi emerges above the water surface, which makes it easy to record the time required for the emergence process (Table 10). The time ranged from 4 to 10 minutes, averaging 6.63 minutes. We noted no significant difference between subimagos emerging in the field and in the laboratory. The range of 4 to 10 minutes was probably caused by individual variability, the more vigorous individuals requiring less time to emerge.

Emerging nymphs crawl completely out of the water. At Rocky Comfort Creek they crawled 1½ to 4 inches above the surface of the water to a point just above the wet portion of the stumps (Fig. 23). In places without objects sticking from the water, we have found nymphal skins or exuviae attached just above the wet portion of the stream bank. In the laboratory the nymphs crawled 1 to 2 inches above the surface of the water on the strips of plastic screen. Occasionally nymphs emerged on the screen with the apical third of their caudal filaments still in the water, a phenomenon never observed in the field.

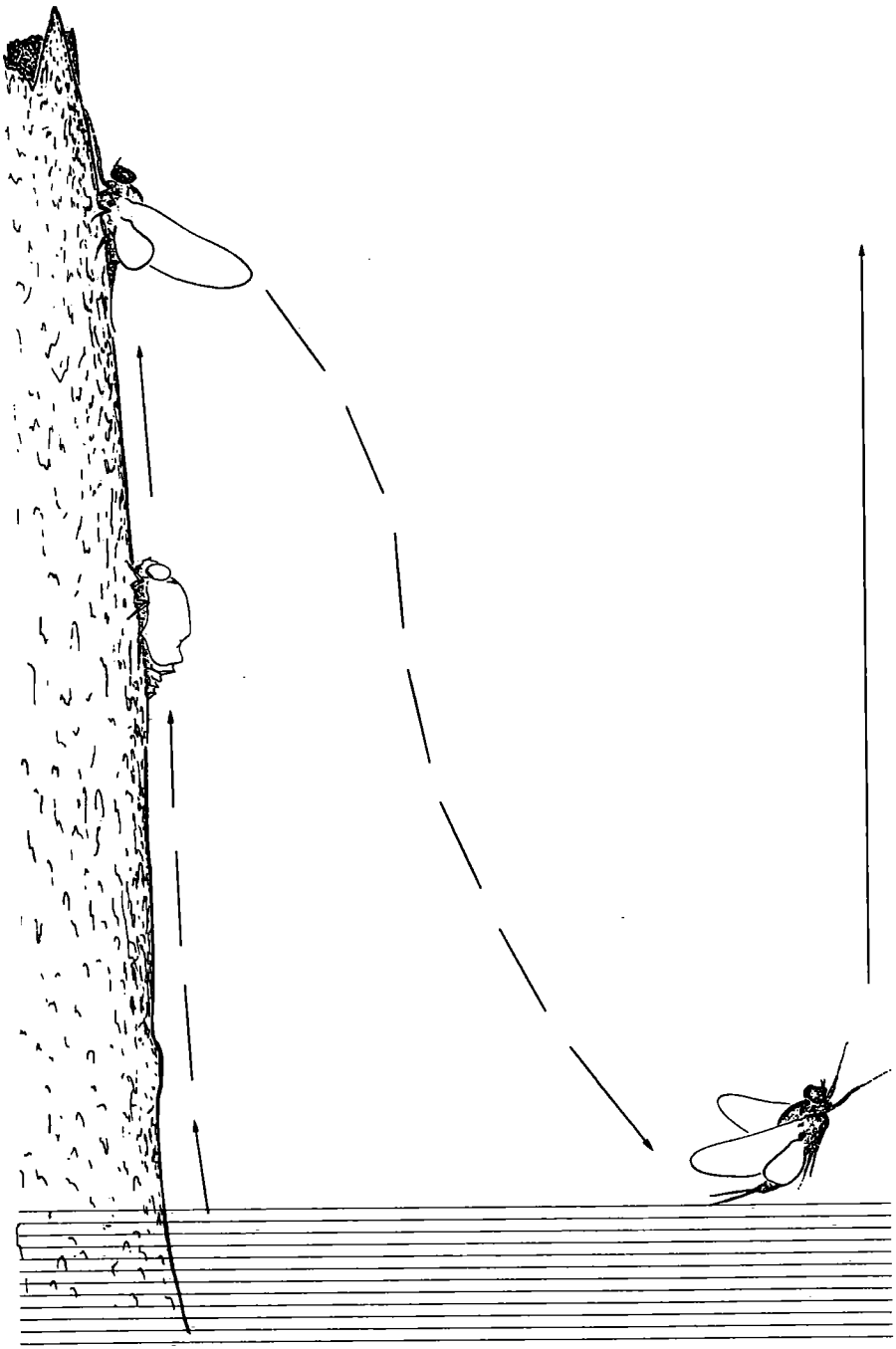

FIGURE 23.—Flight pattern of *B. rogersi* subimago.

The distance that the nymphs crawl above the water surface appears to be related to the wave action (splash condition) of the water. Nymphs emerging in the field crawled farther above the water to find a dry surface than did those in the laboratory.

The emergence process began with a small medial split of the thoracic notal shield. The abdominal segments contracted repeatedly in a peristaltic fashion followed by the outward bulging of the thorax until the entire middle medial line of the mesothoracic notal shield opened. The split gradually progressed anteriorly and posteriorly. Anteriorly it reached the vertex of the head, usually between the compound eyes along the obscured ecdysial line, but sometimes extended to the base of the frontal process of the head. Posteriorly the split terminated at the posterior margin of the median carina. As the split progresed, the subimago wriggled out from the old skin. The dorsum of the subimaginal thorax emerged first, followed by the compound eyes and then the head. At this point the emerging subimago assumed a slanted position with the head and anterior half of the thorax completely exposed, and the abdomen still encased in the old cuticle. Quick jerky body movements and abdominal contractions completed the process with the release of the abdominal segments and caudal filaments. Sometimes the subimago spread out its prothoracic legs immediately upon exposure and firmly anchored the claws on the supporting objects. This probably helped the emerging subimago pull itself from the nymphal skin. Normally the prothoracic legs and the mesothoracic legs remained firmly drawn under the venter of the thorax until the metathoracic legs appeared and all three pairs spread out at the same time. At emergence the wings of the subimago were moist and often curled at the apex.

A newly emerged subimago remains motionless for awhile, and then crawls up on the supporting object. This resting behavior probably allows the subimago time to regain its strength and dry its wings.

Flight Activities

The subimagos of *B. rogersi* have a unique flight pattern (Fig. 23). They dive to the water surface and then fly vertically up into the air. The functional significance of this behavior remains unknown. The subimagos are strong flyers, flying up out of sight in a few seconds. Their ability to fly fast perhaps helps them avoid predators.

Duration

The duration of the subimaginal stage of *B. rogersi* at laboratory temperatures ranged from 11 hr 50 min to 30 hr, averaging 21 hr. 21 min.

TABLE 11.—DURATION OF SUBIMAGOS OF *Baetisca rogersi* AT DIFFERENT TEMPERATURES.

Air Temp. ° C	Number	Range of duration (hours)	Average Duration
19.4–20.6	6	15 hr 30 min—34 hr	23 hr 44 min
21.1–22.2	9	17 hr 5 min—30 hr	24 hr 26 min
25.5–26.7	4	16 hr 55 min—23 hr 30 min	19 hr 38 min
27.2–28.3	4	11 hr 50 min—25 hr 50 min	18 hr 57 min

Although individual variations occurred, higher temperatures seemed to shorten the subimaginal stage. Table 11 includes only those subimagos for which exact durations are known. No experimental work was done, but these observations support Lyman's (1944) conclusion that temperature controls the length of the subimago stage.

Relative humidity in the laboratory ranged from 33% to 77%, and did not appear to affect the subimagos' duration.

MOLTING

The molt from subimago to imago required 8 to 11 minutes and averaged 9 min 45 sec for five laboratory specimens. The mechanism was similar to subimaginal emergence from nymphs, except that the ecdysial line of the head vertex split first, followed by the median dorsal line of the thorax. The head appeared first, then the thorax. Finally the imago pulled the abdomen, wings, and caudal filaments from the subimaginal skin with strong undulations of the body.

PREDATION

Spiders on tree stumps where nymphs emerged preyed upon the subimagos. On several occasions, the senior author saw spiders seize newly emerged subimagos. Most of the subimagos were able to escape by beating their wings strongly. Birds also preyed upon the subimagos.

The amount of subimago mortality from predation is unknown, but the color pattern of *B. rogersi* appears to provide excellent camouflage. The mottled pattern of the wings obscures the red spot (conspicuous in the imagos) and breaks up the outline of the wings. Newly emerged subimagos were difficult to recognize when motionless on the tree stumps.

THE IMAGOS

EXTERNAL MORPHOLOGY

Male Imagos (live specimens) (Fig. 1): Length: Body 6.5-8.6 mm; fore wings

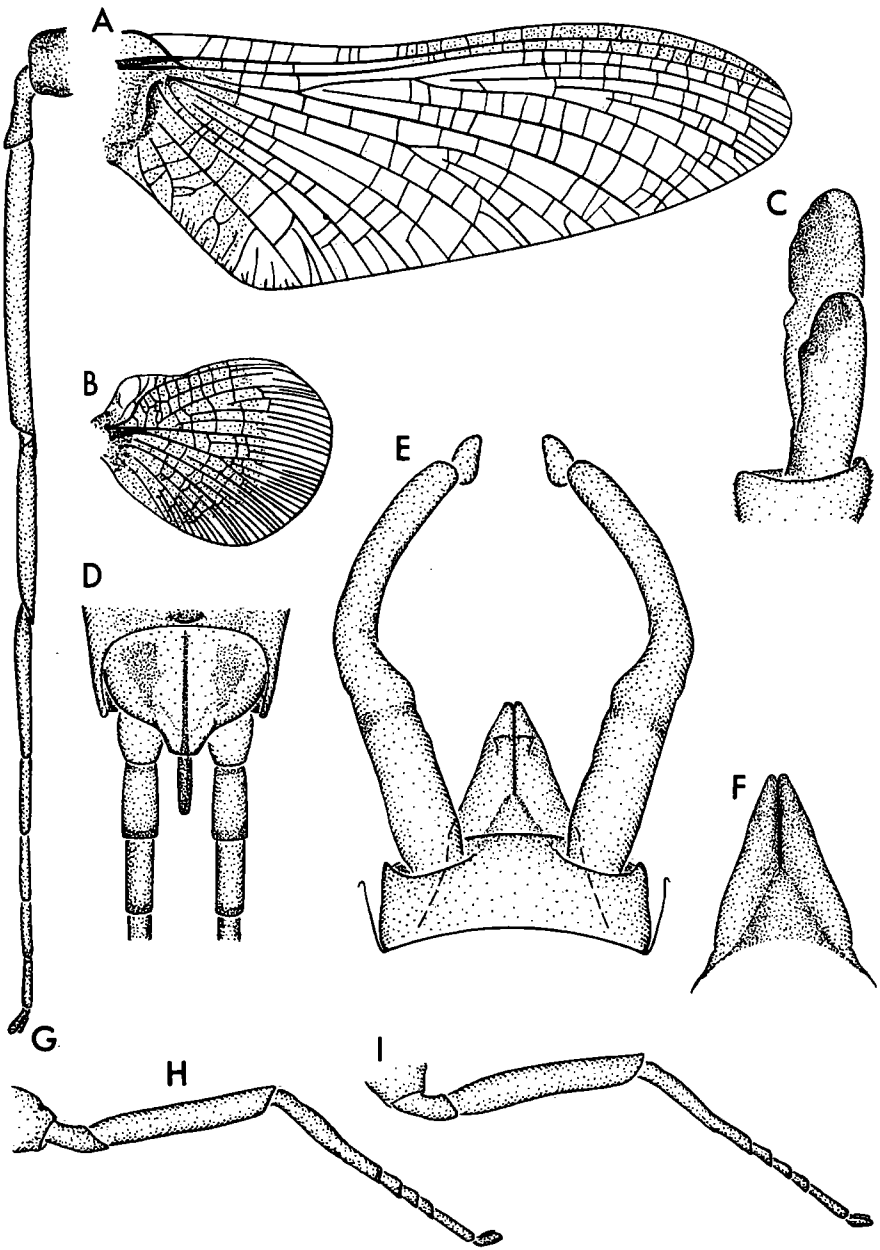

FIGURE 24.—Male imago of *B. rogersi*: A) fore wing; B) hind wing; C) fore claw; D) dorsal view of abdominal segment 10 and base of caudal filaments; E) ventral view of genitalia; F) dorsal view of penes; G) prothoracic leg; H) mesothoracic leg; I) metathoracic leg.

8.0-9.5 mm; caudal filaments 5.5-7.0 mm. Head: dark brown, orange near base of ocelli, blackish at posterior margins of vertex, vertex with whitish granulations in some specimens; dorsal surface of genae near base of compound eyes grayish-yellow; frons grayish except adjoining areas surrounding ocelli brownish-yellow. Antennae: pale, basal segments washed with brown; antennal socket and pedicel brown, segment 2 lighter, remainder of segments pale. Compound eyes grayish-yellow with very minute stipplings. Ocelli yellowish-white, yellowish-orange near base. Thorax: pronotum narrow, dark brown except median line pale; mesonotum grayish-brown, darker at median area; mesonotum with minute black stipplings; parapsidal furrows reddish-brown, with whitish granulations in some specimens; mesoscutellum saddle-shaped, reddish-brown, darker at margins, blackish at posterolateral corners. Metanotum membranous, entirely covering abdominal segment 1. Pleural areas of pronotum dark brown; epimeron and episternum of mesothorax and metathorax including the axillary sclerites reddish-black, remainder of pleuron grayish. Prosternum brown, submedian projections dark brown, and extended beyond posterior bases of fore coxae; mesosternum and metasternum grayish-yellow; ventral extension of pleurotrochantin near basisternum smoky brown; basisternum covered with whitish granulations in some specimens; sutures of mesosternum and metasternum grayish with minute black stipplings. Legs (Fig. 24 G-I): prothoracic legs pale yellowish-brown; mesothoracic and metathoracic legs pale yellow except dorsal surface washed with brown; dorsal surface of each tarsal segment with a brown transverse band at apex; dorsum of fore claws brown; tarsal claws of fore legs rounded at apex (Fig. 24 C); ratios of segments in male fore legs 1.40:1.00(1.35 mm):0.72:0.40:0.40:0.31:0.23; mesothoracic and metathoracic legs 1.41:1.00(0.82 mm):0.21:0.21:0.14:0.43. Wings (Figs. 1, 24 A,B): longitudinal veins of fore and hind wings amber, pale near margins; costal margins of fore wings prominently emarginated, thickened; basal 1/3 of fore wings reddish-brown; humeral area grayish. Apex of hind wings a little obtuse; basal 3/4 of hind wings reddish-brown. Abdomen terga 1-5 reddish-brown, darker at margins; prominent pale spiracular openings on terga 1-6; terga 6-9 light reddish-brown, darker at posterior and lateral margins on segments 6-8; tergum 10 as in Figure 24 D, yellowish; prominent dorsal elevation on posterior 1/2 of tergum 6 strongly marked with fine black stipplings; sterna 1-8 grayish-white, darker at lateral margins; sternum 9 pale, presence of fine black stipplings near anterior and posterior margins; lateral borders of terga 1-5 reduced into a small pad-like structure; posterolateral margins of sterna 7-9 with projections, elongated into spines on sternum 9. Genitalia (Fig. 24 E,F): genital forceps and penes yellowish-white; forceps 2-segmented, distal 1/2 of segment 1 prominently curved; apical segment small, conical; penes triangular (Fig. 24 F), proximal 2/3 fused. Caudal filaments: cerci yellowish-brown, pale at apex; basal 2/3 of cerci with brown annulations at articulations; basal 1/2 of median filament reddish-brown, remainder of filament hyaline.

Female Imagos (live specimens): Length: Body 7.5-9.2 mm; fore wings 9.0-11.0 mm; caudal filaments 5.0-5.4 mm. Head: dark brown with black markings along median area of vertex; color pattern of dorsal surface of genae near base of compound eyes as in male imagos; vertex with whitish granulations in some specimens. Frontal area of head as in Figure 25 A. Compound eyes smaller than in male imagos, grayish-yellow; ocelli yellowish, reddish-brown at base. Color and markings of antennae as in male imagos. Lateral areas of head as in Figure 25 B. Thorax: color pattern of thorax as in male imagos; inner parapsidal furrows and median carina of thoracic notal shield darker. Prosternum dark brown, submedian process shorter and more widely separated than in male imagos. Legs: femora of prothoracic legs yellowish-brown, remainder of legs light brown, markings of fore legs as in male imagos; color pattern of mesothoracic and metathoracic legs as in male imagos. Ratios of segments in female fore legs 1.17:1.00(0.96 mm):0.21:0.21:0.17:0.34; mesothoracic and metathoracic legs 1.42:1.00(0.96 mm):0.18:0.18:0.13:0.37. Abdomen: color pattern of abdomen as in male imagos, except terga 1-5 of some individuals darker. Sterna 4-7 with dark brown median line in some specimens; posterior margin of sternum 9 con-

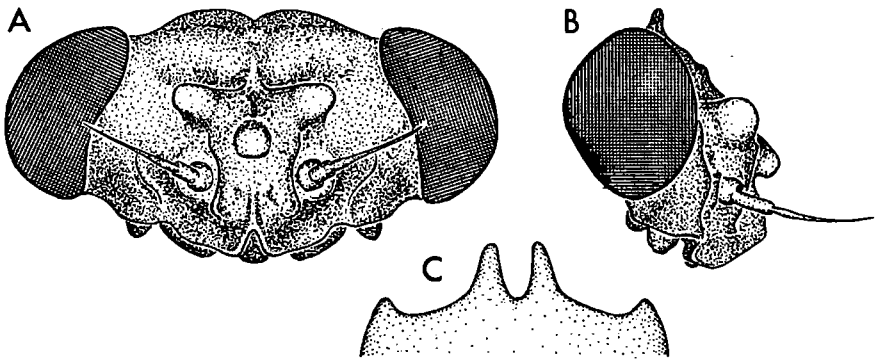

FIGURE 25.—Female imago of *B. rogersi*: A–B) frontal and lateral view of head; C) ventral view of ninth abdominal sternite.

cave forming a bifid subanal plate with a deep V-shaped median cleft (Fig. 25 C). Caudal filaments: color pattern of cerci as in male imagos; basal 1/2 of median filament reddish-brown; remainder pale.

FLIGHT ACTIVITIES

Since Berner (1940) first described *Baetisca rogersi*, no one has seen the imagos swarming or in flight. The imagos probably swarm in companies or individually at a very high altitude, as do many mayfly species. Repeated attempts to find swarming or mating imagos in the field were fruitless.

Similarly we have never seen female imagos laying eggs, and most species of mayflies show specific oviposition behavior. *B. rogersi* females may lay eggs at night or they may migrate upstream to oviposit.

LIFE SPAN

Imagos of *B. rogersi* lived from 8 hr 30 min to 28 hr 20 min in the laboratory, averaging 21 hr 8 min. Within the relatively small laboratory variations, temperature and relative humidity had no demonstrable effect on life span. Specimens exposed to more or less the same temperature and humidity lived for varied times, with some individuals living almost four times longer than others. This life span range could be a result of biological variation among individuals, or of unnoticed damage to some of the specimens after emerging. No significant differences in life span existed between males and females.

PARTHENOGENESIS

Viviparity and parthenogenesis occur in many mayflies species, but until now neither has been reported in any species of *Baetisca*.

TABLE 12.—NUMBER OF EGGS PRODUCED BY INDIVIDUAL *Baetisca rogersi* FEMALES.

1968		1969	
Date Collected	No. of eggs	Date Collected	No. of eggs
April 27	2539	March 11	2650
April 27	2727	March 28	2600
April 29	2137	April 1	2551
May 1	2540	April 1	2021
May 3	2134	April 10	2302
May 5	1590	May 7	2400
May 8	1800	May 15	2500
May 11	1590	May 19	1500
May 13	1876		
May 17	2003		
June 30	1721		
Average number of eggs/female = 2168			

[1]Extracted from preserved specimens.

To determine parthenogenesis, eggs extracted from an unmated female subimago on 27 April 1968 were incubated in the laboratory. Out of a total of 2,726 extracted eggs, 9 nymphs hatched, representing approximately 0.33% (Table 1). On 30 June 1968 and 11 March 1969 we repeated the experiment. Ten nymphs (from 1,721 eggs) and 12 nymphs (from 2,650 eggs) hatched. On 1 April 1969 we extracted 2,551 eggs from an unmated female imago; 38 nymphs hatched. Although the percentage of unfertilized eggs that hatched was very low compared to fertilized eggs (Table 1), the data indicate that parthenogenetic development can occur in *B. rogersi*. Further, the fact that eggs extracted from subimagos hatched suggests that eggs are mature in the subimaginal stage.

The ratio of males to females was more or less equal. Combined results for two years showed a 0.81:1.00 ratio (49 males, 59 females) for adults reared in the laboratory. Of 408 nymphs collected from the two localities, 194 were males and 208 were females, a 0.90:1.00 ratio. *B. rogersi* can be parthenogenetic, although males and females are more or less equal in proportion.

EGG NUMBER

Table 12 gives egg counts made on 19 females of *B. rogersi*. The average number of eggs per individual was 2,168. In 1969 the largest number was 2,650 and the smallest was 1,500. As individuals emerging late in the season are usually smaller than those emerging earlier, it was

expected that they would produce relatively fewer eggs. Table 12 shows this to be generally true.

Seasonal Distribution

The seasonal distribution of imagos as determined from emerging subimagos extended from March through early July. Tables 3 and 4 show that twelfth instar nymphs first appeared in February, increasing in March. Emergence began in March. The earliest emergence record in the field was 13 March 1969 and the latest 8 July 1969, but, we revisited the stream the following week and found two more nymphal exuviae on stumps. The exact emergence date of these specimens cannot be ascertained because the exuviae were decolorized and disintegrated. Newly cast nymphal exuviae retain the color of the last nympal instar for a day, and the linings of the rupture are whitish in color. We made several more attempts to collect imagos, nymphal exuviae, and nymphs in the following weeks, but found none. In the laboratory, the earliest emergence was 10 March 1968 and the last 30 June 1968. In 1969 emergence extended from 9 March to 26 June. One twelfth instar nymph however remained alive until July but did not emerge.

The peak of emergence occurred in April both years (Tables 3 and 4). Laboratory emergence records also showed an April peak. Emergence did not extend past the middle of summer, reflecting a strictly seasonal distribution permitting only one generation a year.

Summary

We studied the life history, ecology, and seasonal distribution of *Baetisca rogersi* in the laboratory and in Rocky Comfort and Bear Creeks, Gadsden County, Florida, 1967-1969. In the laboratory fertilized eggs began to hatch in 20-31 days, averaging 23.8 days, and unfertilized eggs averaged 26.6 days. We found nymphs in the study areas from September through June and assume that eggs remained dormant during the summer. We raised twelve nymphal instars in the laboratory, a nymph taking approximately four months to mature. In the field, early instar nymphs lived on a substratum with water moss, *Leptodictyum riparium*, and filamentous algae, *Spirogyra* sp. Mature nymphs at Rocky Comfort Creek lived in shallow areas of gravel and sand. In Bear Creek, a sand bottom stream, the nymphs lived on submerged logs or in the sand. Twelfth instar nymphs migrated to quiet sections of the stream prior to emergence, probably searching for above-water objects where the nymphs could emerge.

The nymphs swim with vigorous and rapid undulations of the last

three abdominal segments including the caudal filaments, using the gills only for respiration. The lateral spines of the thoracic notal shield balance and maintain the dorsoventral position of the nymphs. The nymphs feed on detritus, diatoms, and fragments of filamentous algae; they feed at night. In the field, nymphal growth slowed in December and January and resumed in the latter part of January.

Emergence was strictly seasonal, permitting only one generation per year. Subimagos emerged from March through early July with the peak emergence in April. They emerged in the field between 8:30 AM and 2:30 PM with a peak between 8:30 AM and 10:30 AM. In the laboratory they emerged from 10:00 AM to 8:30 PM (peak emergence from 12:00 PM to 3:00 PM). The duration of the subimaginal stage ranged from 12 to 30 hours, averaging 20 to 24 hours. The imagos lived an average of 21 hr 8 min in the laboratory. Female imagos produced 1,500 to 2,727 eggs averaging 2,168 eggs.

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