

LIFE HISTORY AND PRODUCTIVITY OF *HEXAGENIA LIMBATA* (EPHEMEROPTERA: EPHEMERIDAE) AND SELECTED PHYSICO-CHEMICAL PARAMETERS IN TWO TRIBUTARIES OF THE WEKIVA RIVER, CENTRAL FLORIDA

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ABSTRACT

Nymphal densities and size frequency distribution of *Hexagenia limbata* (Serville), a burrowing mayfly, were determined monthly for two years in two tributaries of the Wekiva River, central Florida, along with selected physico-chemical water parameters. Blackwater Creek supported a mean number of 112 (range 0-434) and Rock Springs Run 89 nymphs per m<sup>2</sup> (range 11-258). The mayfly species displayed a univoltine life history with adult emergence peaking in August. Productivity in Blackwater Creek was estimated at 4.688 g per m<sup>2</sup> and in Rock Springs Run at 3.123 g per m<sup>2</sup>. Productivity/biomass ratios were estimated at 4.09 and 4.59 in Blackwater Creek and Rock Springs Run, respectively. The nymphal densities in both streams were positively correlated with water pH and negatively correlated with water volume. Apparently, water volume was the overriding abiotic factor in both streams, influencing several measured water parameters and as well as nymphal populations during the study period.

Key Words: Mayfly, life history, streams, size frequency distribution, physico-chemical parameters, productivity

RESUMEN

Las densidades ninfales y la distribución de frecuencia de tamaño de la efímera *Hexagenia limbata* (Serville), así como parámetros físico-químicos de agua seleccionados, fueron determinados mensualmente durante dos años en dos tributarios del río Wekiva, en Florida Central. El arroyo Blackwater tuvo un promedio de 112 (rango 0-434) y Rock Springs Run 89 ninfas por m<sup>2</sup> (rango 11-258). Las especies de efímeras mostraron un ciclo de vida univoltino con el pico de emergencia de los adultos en Agosto. La productividad del arroyo de Blackwater fue estimada en 4.688 g por m<sup>2</sup> y en Rock Springs Run en 3.123 g por m<sup>2</sup>. Las tasas de productividad/biomasa fueron estimadas en 4.09 y 4.59 en los arroyos Blackwater y Rock Springs Run, respectivamente. Las densidades ninfales en ambas corrientes estuvieron positivamente correlacionadas con el pH del agua y negativamente correlacionadas con el volumen de agua. Aparentemente, el volumen de agua fue el factor más importante en ambas corrientes, influenciando varios de los parámetros de agua medidos así como las poblaciones ninfales durante el período de estudio.

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*Hexagenia limbata* (Serville) (Ephemeroptera: Ephemeridae) is one of the most geographically widespread mayflies in North America. It is found from coast to coast as well as from Florida to Canada and often constitutes an important part of the macrobenthos of both lotic and lentic aquatic habitats (Berner & Pescador 1988, Hunt 1953). High densities and productivity rates of mayflies such as *H. limbata* may constitute a significant component of nutrient and energy cycling within their aquatic habitats and adjacent terrestrial systems. This would be especially true for Florida, where almost one quarter of the state's land is swamps (Ewel 1990), marshes (Kushlan 1990), lakes (Brenner *et al.* 1990) or streams (Nordlie 1990).

*Hexagenia limbata* has been extensively studied in terms of life history and productivity, but mostly in the northern part of its ecological range. The present study on *H. limbata* was conducted in two tributaries of the Wekiva River, central Florida, to determine its productivity and life history in peninsular Florida and to elucidate the effects of selected environmental conditions. Quantitative samples of *H. limbata* nymphs were collected monthly from each stream for two years for these purposes. Selected physico-chemical parameters in both streams were also measured to determine any relationships of these parameters with spatial and seasonal changes of *H. limbata* populations.

#### METHODS AND MATERIALS

The study streams were located in the Wekiva River basin (a part of the St. Johns River basin), central Florida (Fig. 1). Blackwater Creek is about 40 km long and is a second order sand bottom stream with both calcareous and swamp-bog stream aspects (Beck 1965). Rock Springs Run is a first order calcareous stream (Beck 1965) about 14.5 km long. Water current in both streams varied from 2-50 cm per sec; local variation in current velocity resulted in substrates which varied from exposed sand to thick deposits of detritus and silt.

For sampling *H. limbata* nymphs and for measuring selected physico-chemical parameters, 10 sampling stations were selected in each stream. These stations were approximately 400 m apart in Blackwater Creek and 1200 m apart in Rock Springs Run. The exact locations of the sampling stations were determined by coordinates using a Panasonic model LX-G5500 Global Positioning System receiver (Panasonic Company, Secaucus, NJ). Each stream was sampled on a monthly basis from February 1993 to January 1995. Samples were collected between 0830 and 1230 hours local time each sample day.

Selected physical and chemical parameters were measured *in situ* close to the sediment-water interface at, or very near, each sampling station with portable meters or appropriate field kits. The parameters included: current velocity, water pH, dissolved oxygen, turbidity, nitrate-N, conductivity, water temperature and secchi disk transparency. Water volume in the streams was estimated using mean water elevation (Blackwater Creek) or cumulative rainfall (Rock Springs Run) for 30 days previous to a sampling date. Details concerning the various meters, field kits, determination of water volume and data handling were presented in Lobinske *et al.* (1996).

For quantitative sampling of *H. limbata*, one benthic sample was collected from each station with a 15 × 15 × 15 cm Ekman dredge mounted on a 1.5 m steel pole (APHA 1992). Samples were washed immediately using a sieve bucket with a 350 μm pore screen and the collected material appropriately labeled and stored on ice until returned to the laboratory.

All collected samples were examined and analyzed within 48 hours. The mayfly nymphs were identified to species using the keys of Berner & Pescador (1988) and length of each determined to the nearest mm under 2-40X magnification. Wet weight

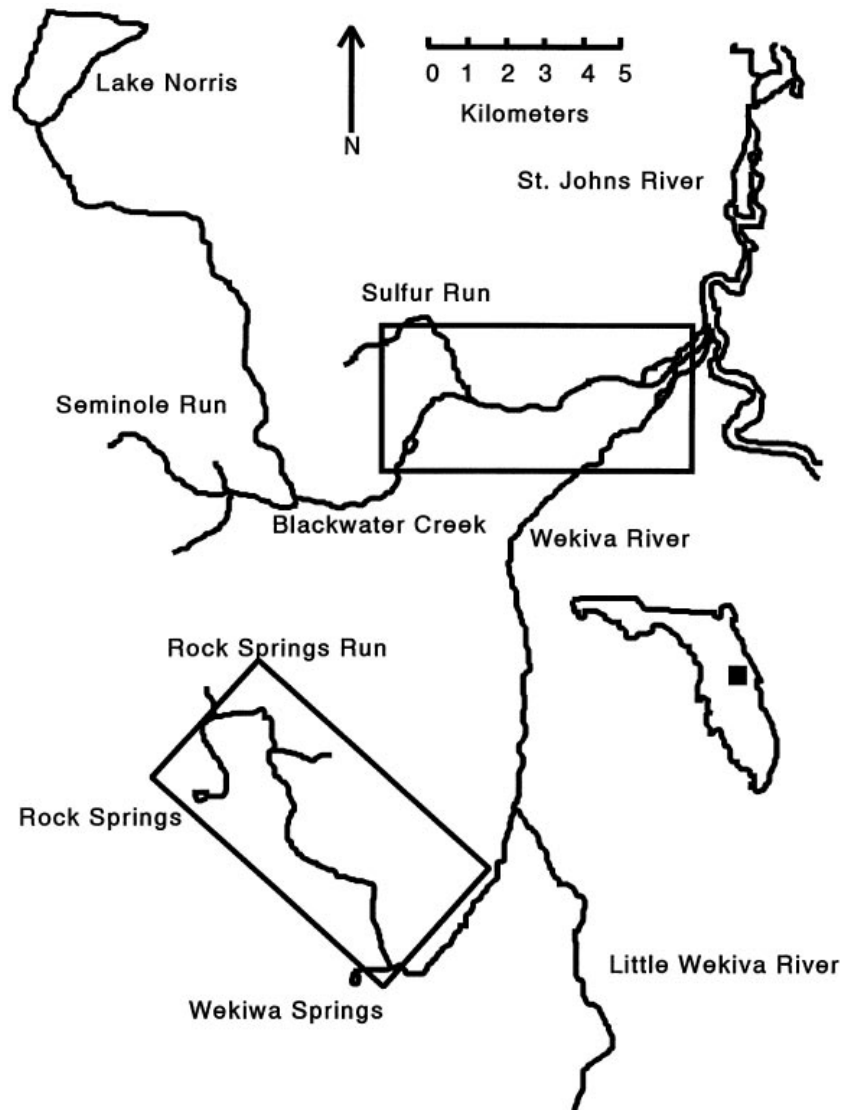


Fig. 1. Map of the Wekiva River Basin, central Florida, with Blackwater Creek and Rock Springs Run study areas marked by boxes. Relative location of the general study area is marked on outline map of Florida.

of nymphs was determined from length using the formula of Heise *et al.* (1988) and dry weight determined using the formula of Hudson & Swanson (1972). Productivity was estimated using the size-frequency method (Hynes & Coleman 1968, Hamilton 1969). Voucher specimens were deposited with the University of Central Florida Collection of Arthropods, Orlando, FL, and with the Florida State Collection of Arthro-

Pods, Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville, FL.

Statistical analysis of collected nymphal and physico-chemical data and their graphical presentation were made by utilizing InStat V. 2.04 (Graphpad Software, Inc., San Diego, CA) and SlideWrite Plus V. 6.0 (Advanced Graphics Software, Inc., Carlsbad, CA). Where needed, data were transformed using log (n+1) transformation to improve homoscedasticity.

#### RESULTS

Overall density of *H. limbata* nymphs in Blackwater Creek was 112 per m<sup>2</sup> and in Rock Springs Run 89 per m<sup>2</sup> for the 2-year study period. The density difference between the two habitats was statistically not significant ( $P>0.05$ ). Trends of nymphal populations in each stream are summarized in Fig. 2. In Blackwater Creek, maxima (434 nymphs per m<sup>2</sup>) were taken in September 1993, while the highest nymphal density in Rock Springs Run (258 per m<sup>2</sup>) occurred in January 1994. Monthly densities ranged from 11-258 nymphs per m<sup>2</sup> in the latter habitat and from 0-434 nymphs per m<sup>2</sup> in the former. Heavy summer rains and Tropical Storm Gordon in November 1994 caused excessive flooding which seemed to have a decimating effect on *H. limbata* populations, especially in Blackwater Creek where no nymphs occurred in the January 1995 samples. Monthly size frequency distribution of *H. limbata* nymphs in the two streams (Fig. 3) reveals a univoltine life cycle with peak emergence occurring in mid-August. Productivity estimates of *H. limbata* in Blackwater Creek amounted to 4.688 g per m<sup>2</sup> and 3.123 g per m<sup>2</sup> in Rock Springs Run. Mean dry biomass was estimated at 1.146 g per m<sup>2</sup> for Blackwater Creek and 0.681 g per m<sup>2</sup> for Rock Springs Run. The productivity/biomass (P/B) ratios of *H. limbata* were 4.09 and 4.59 for Blackwater Creek and Rock Springs Run, respectively.

Trends of selected physico-chemical parameters in each habitat during the study period are shown in Fig. 4. Relationship of these parameters with the nymphal populations examined by linear correlation analysis showed some significant relationships: For example, water pH ( $r=0.62$ ,  $P<0.01$ ,  $n=23$  for Blackwater Creek and  $r=0.61$ ,  $P<0.01$ ,  $n=23$  for Rock Springs Run), nitrate-N ( $r=0.63$ ,  $P<0.01$ ,  $n=21$  for Blackwater Creek and  $r=0.54$ ,  $P<0.05$ ,  $n=20$  for Rock Springs Run) and water volume ( $r=-0.60$ ,  $P<0.01$ ,  $n=24$  for Blackwater Creek 30-day mean water elevation and  $r=-0.62$ ,  $P<0.01$ ,  $n=24$  for Rock Springs Run 30-day cumulative rainfall). No significant correlations were found between nymphal populations and the other physico-chemical parameters shown in Fig. 4. Combined nymphal data from both streams also showed significant correlations with combined water pH values ( $r=0.59$ ,  $P<0.0001$ ,  $n=46$ ) but not with nitrate-N ( $P>0.05$ ); water elevation for Blackwater Creek and rainfall data for Rock Springs Run were not possible to combine for the cumulative (combined) effect analysis.

#### DISCUSSION

The univoltine life cycle of *H. limbata* determined in the present study is in complete agreement with the previous observations noted by Berner & Pescador (1988) in Florida, as is the emergence peak in August. The mean densities of *H. limbata* in Blackwater Creek and Rock Springs Run are compatible with *H. limbata* density reports of 41 to 153 per m<sup>2</sup> for Lewis and Clark Lake, South Dakota/Nebraska (Swanson 1967), and for South Indian Lake (20-130 per m<sup>2</sup>), Manitoba, Canada (Giberson & Rosenberg 1994). However, some streams in the Eglin Air Force Base Reservation in north Florida had supported <14 *H. limbata* nymphs per m<sup>2</sup> (Scheiring *et al.* 1981, Scheiring & Crews 1983).

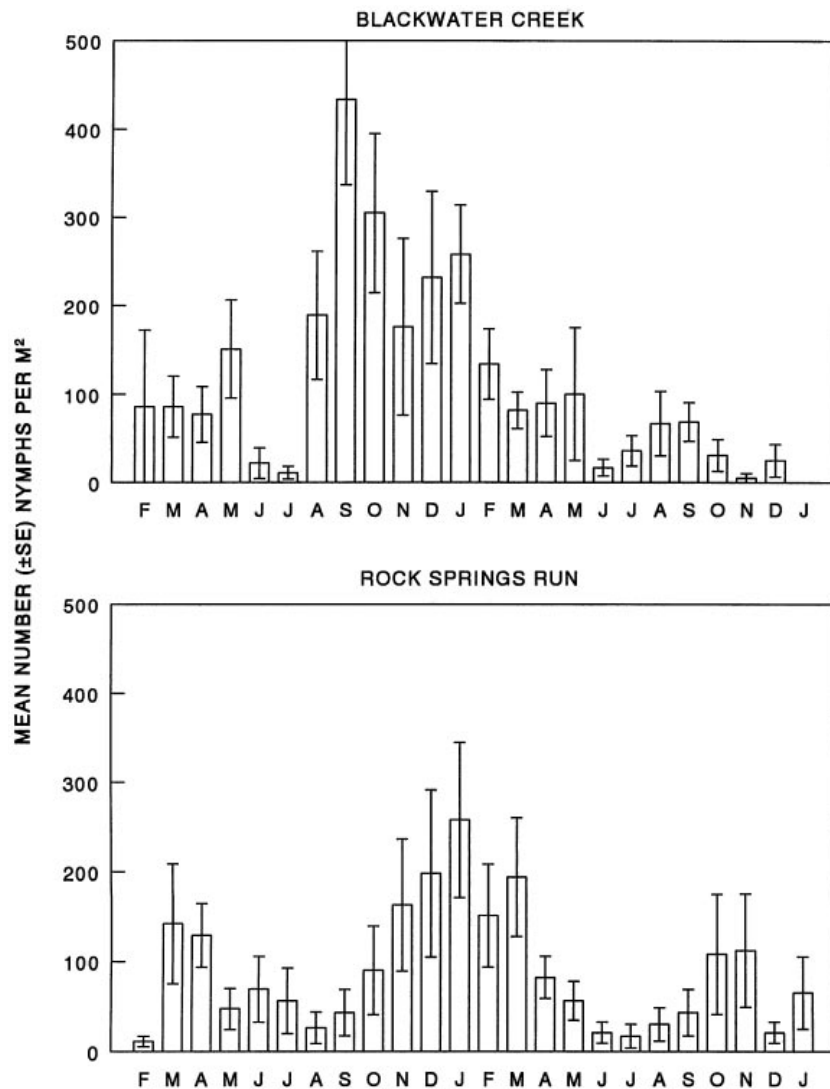


Fig. 2. Monthly mean population trends of *Hexagenia limbata* nymphs in Blackwater Creek and Rock Springs Run, central Florida (February 1993 to January 1995).

The *H. limbata* productivity rates of 4.688 g per m<sup>2</sup> in Blackwater Creek and 3.123 g per m<sup>2</sup> in Rock Springs Run were much higher than the 0.8 g dry wt per m<sup>2</sup> measured by the size frequency method in Savanne Lake, Ontario, Canada (Riklik & Momot 1982), 1.667 g dry wt per m<sup>2</sup> in Lewis and Clark Lake (Hudson & Swanson 1972), and <1.8 g dry wt per m<sup>2</sup> (determined from <13 g wet wt per m<sup>2</sup>) in Dauphin Lake, Manitoba, Canada (Heise *et al.* 1988). The resulting P/B ratios of *H. limbata* were also

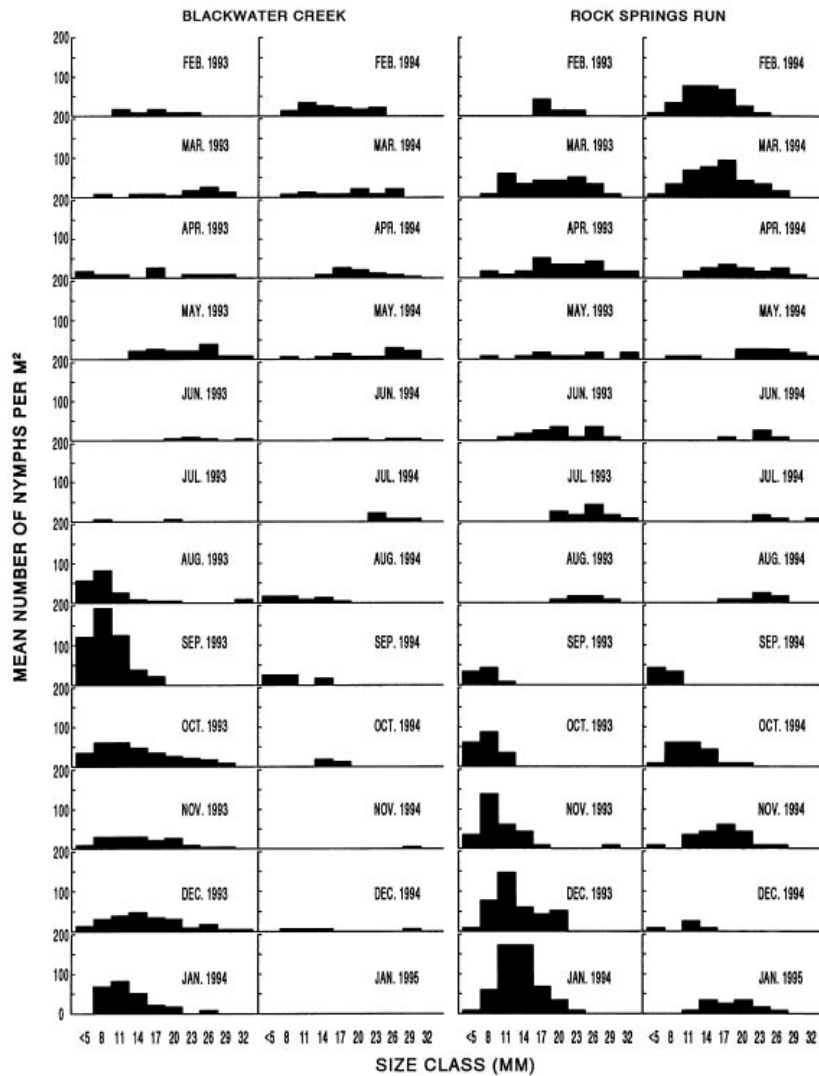


Fig. 3. Monthly size frequency distribution of *Hexagenia limbata* nymphs in Blackwater Creek and Rock Springs Run, central Florida (February 1993 to January 1995).

higher in the present study than the values of 2.6 (Riklik & Momot 1982) and 1.68 to 2.38 (Heise *et al.* 1988) reported from some northern habitats, although a higher value of 5.7 (P/B ratio) was reported by Smock *et al.* (1985) for Cedar Creek, South Carolina. The warmer water temperatures in the investigated streams is probably conducive to more rapid development of *H. limbata*, as also shown experimentally by Fremling (1967) and Giberson & Rosenberg (1992).



The significant relationships between *H. limbata* density and certain water parameters were probably influenced by variations in water volume in the streams. The inverse relationship between water elevation or rainfall and *H. limbata* populations may be due to a direct flushing effect or due to an indirect effect through other water parameters influenced by high water discharge. The positive correlations of *H. limbata* with nitrate-N seem to be coincidental, since this was not true for combined data from both streams. The significant correlations with water pH, for each stream and both combined, indicate a valid pH effect on nymphal density. The pH range (6.20-7.89 for Blackwater Creek and 6.89-7.98 for Rock Springs Run) at which *H. limbata* occurred in the study streams is in agreement with the water pH range of 6.0-7.9 for this species reported by Roback (1974).

This study provides an initial database on the life history and productivity of *H. limbata* in small lotic systems of peninsular Florida. This mayfly is an important component of the ecosystems studied. Using a hypothetical 5 m width, *H. limbata*'s annual production for Blackwater Creek would be 937.6 kg dry wt and 226.4 kg dry wt for Rock Springs Run. This, combined with the high P/B ratios, indicate that this mayfly contributes greatly to nutrient cycling and energy flow within these streams and to adjacent terrestrial systems.

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