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# South Carolina mayflies (Insecta: Ephemeroptera) of Conservation Concern

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Abstract: Nine mayfly species (Insecta: Ephemeroptera) that may be of conservation concern in South Carolina are discussed. Three such species associated with sand-bottomed streams are *Acanthametropus pecatonica* (Burks, 1953), *Dolania americana* Edmunds & Traver, 1959 and *Homeoneuria dolani* Edmunds, Berner & Traver, 1958. Three species of potential concern are associated with Hornleaf Riverweed (*Podostemum ceratophyllum* Michaux, 1803), and they include *Barbaetis benfieldi* Kennedy, 1985, *Heterocloeon bernerii* (Muller-Liebenau, 1974) and *Tsalia bernerii* (Allen & Edmunds, 1958). Mayflies of slow or stagnant waters that may be of conservation concern in South Carolina include *Arthroplea bipunctata* (McDunnough, 1924), *Maccaffertium lenati* (McCafferty, 1990) and *Siphonurus decorus* Traver, 1932. Biological, ecological and geographic distribution studies of each species are reviewed. The South Carolina record of *A. bipunctata* is questionable. New data are provided for *S. decorus*.

## Introduction

South Carolina is home to 185 documented species of mayflies (Insecta: Ephemeroptera), making it one of the North American states or provinces with greatest species richness; it is arguably second only to neighboring North Carolina, which has at least 207 species<sup>1-3</sup>. Nine of South Carolina's mayfly species should be considered species of potential conservation concern within the state. In several cases, the species are threatened throughout their global range; in other cases, only their South Carolina populations may be in jeopardy. Even if the latter case is true, the South Carolina populations historically may have represented important genetic reserves due to their being either isolated, or to their being on the periphery of the overall geographic distribution of the species.

During the species evaluation period of this project, it became apparent that South Carolina's rarest mayflies fell into three distinct larval habitat categories: sand-bottomed streams, streams with Hornleaf Riverweed (*Podostemum ceratophyllum* Michaux, 1803) and slow or standing waters. Each of these habitats faces significant threats.

## Critical habitat 1: sand-bottomed streams

Streams with shifting sands tend to have benthic macroinvertebrate communities that are low in diversity, but highly specialized in their morphologies and behaviors. In general, these habitats are neglected by biologists, due in part to their low diversity<sup>4</sup>, but also due to difficulties associated with working in deep, swift water, with an unstable bottom<sup>5</sup>. However, macroinvertebrate denizens of these habitats have been generally under pressure for many years<sup>6,7</sup>, and the psammophilous mayflies, in particular, may be in serious jeopardy<sup>4</sup>, due to threats from habitat alteration and pollution. For the conservation requirements of these species to be addressed properly, significant time and effort will need to be expended, using specialized equipment and techniques. Until a comprehensive assessment can be done and new data collected on a broad scale, the following should be considered species of potential conservation concern.

## *Acanthametropus pecatonica* (Burks, 1953)<sup>8</sup> (Acanthametropodidae)

This species has been listed on the Wisconsin Endangered and Threatened Species List and has been considered endangered throughout its entire range of geographic distribution. Notably, it has been extirpated from parts of its range in Illinois and Wisconsin<sup>5</sup>. Aside from these two states, the species is known only from single historical locations in Georgia and South Carolina<sup>3,4,9</sup>. In South Carolina, it is known only from the Savannah River in Barnwell County. The only confirmed South Carolina record data<sup>10</sup> for this species are based on specimens taken at Mile 157 in May 1952<sup>2</sup>. Some differences may exist between the Southeast and Upper Midwest populations<sup>11</sup>, but these populations have been considered to be of a single species<sup>4</sup>. If the populations eventually prove to represent different species, then the outlook for the southeastern variety will be even more dire. *Acanthametropus pecatonica* has been considered to be a vulnerable southeastern species<sup>12</sup>, and it has been listed officially as such<sup>13</sup>. In Wisconsin, the species is found in moderate- to large-sized, fairly rapid streams with rocky, but dominantly sandy, substrates in late spring through middle summer<sup>5,14,15</sup>. In particular, it has been found in rapidly shifting, fine silt and sand habitats, in current of about 0.5 – 1.0 m/s at a depth of about 0.5-1.5 m. The species appears tolerant of warm and at least somewhat eutrophic conditions, as long as the dissolved oxygen levels remain relatively high; some of its streams receive wastewater treatment effluents upstream of the species' habitat. Difficulties associated with sampling the species' habitat contributes to its scarce collection. No data are available about the population density of the species, but it might be relatively abundant in the extremely localized, proper habitat conditions, even though no large number of specimens ever has been collected at a single time<sup>5</sup>. Although no data are available about the diet and feeding behavior of this species, its mouthpart morphology suggests it is a predator, perhaps on chironomid midge larvae (Diptera: Chironomidae), like other species in its family<sup>16</sup>. The highest protection possible has been recommended for historical locales of this species until more research can be done<sup>5</sup>.

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***Dolania americana* Edmunds & Traver, 1959<sup>17</sup> (Behningiidae)**

This is an eastern United States species that is known in South Carolina from only two streams: the Savannah River and Upper Three Runs Creek<sup>2,18</sup>. It is primarily a species of the Southeast, but a disjunct population is known from Wisconsin<sup>3,19</sup>. This disjunct distribution pattern is similar to that seen for *Acanthametropus pecatonica*, above<sup>4</sup>. This has been considered to be a vulnerable southeastern species<sup>12</sup>, and it has been listed officially as such<sup>13</sup>. Further, more extensive discussion of this species is given elsewhere<sup>18</sup>, and will not be repeated here.

***Homoeoneuria dolani* Edmunds, Berner & Traver, 1958<sup>20</sup> (Oligoneuriidae)**

This species is a strictly southeastern United States species<sup>2,21</sup>. In South Carolina, this species is known only from the Savannah and South Saluda Rivers in Allendale, Barnwell and Greenville Counties<sup>20,22,23</sup>. Elsewhere, it is known from Florida and Georgia, with most of the Georgia records being from the Savannah River, and thus shared with adjacent South Carolina<sup>23,24</sup>. The larvae of this species are nearly transparent and thus easily overlooked. They are filter-feeders and live in shallow burrows in sand-beds of swiftly-flowing streams, usually in deeper water, where the substrate is free of vegetation. The species probably has one generation per year, with an extended flight period from late spring through middle autumn; adults swarm from midmorning until about noon on sunny days, about 1 m above the water's surface<sup>25</sup>.

**Critical habitat 2: Hornleaf Riverweed**

Hornleaf Riverweed (*Podostemum ceratophyllum*) plays an important role in providing habitat structure for many aquatic macroinvertebrates<sup>26</sup>. The riverweed may itself be an indicator of environmental health, being sensitive to landscape-level environmental changes<sup>27,28</sup>. Surely, the following mayflies are at least as sensitive. Protection of landscapes that drain into *Podostemum* streams may be warranted.

***Barbaetis benfieldi* Kennedy, 1985 (in Waltz *et al.*, 1985)<sup>29</sup> (Baetidae)**

This is a species of clean, southeastern United States mountain streams, and it is the only species in its genus, representing an important component of regional and global phylogenetic diversity<sup>29,30</sup>. In South Carolina, it is known from three streams in Aiken (Cedar Cr.), Pickens (Cane Cr.) and York (Wildcat Cr.) Counties, with the most recent collections taken in 2000<sup>2</sup>. Outside South Carolina, it has been reported only from North Carolina and Virginia<sup>3</sup>, with it being considered endangered in Virginia<sup>31</sup>. At least nine North Carolina populations have been found, all from far western, mountainous areas, with a concentration near the extreme northwestern tip of South Carolina<sup>32</sup>. This species has been considered to be vulnerable<sup>12,33</sup>, and it has been listed officially as significantly rare in North Carolina<sup>34</sup>. Larvae are associated with Riverweed in stream riffles at a depth of about 0.5-2.5 m where the flow is about 0.5 m/s. Physical and chemical parameters vary widely, including temperature, but dissolved oxygen is always near the saturation point which is typical of rapidly flowing streams. This species has one generation per year, with adults emerging from late April through middle May. This

species drifts at night, with 10 individuals per 100 cubic meters of water having been observed<sup>29</sup>.

***Heterocloeon bernerii* (Muller-Liebenau, 1974)<sup>35</sup> (Baetidae)**

This species is known only from the extreme southern Appalachians<sup>2,35</sup>. It is known in South Carolina from two streams (Flat Shoals R., Little R.) in Oconee County, with the most recent collections being from the former location in 2000<sup>2</sup>. Elsewhere, it is only known from Cherokee and Lumpkin Counties in northern Georgia<sup>3,35</sup>, not far from the extreme northwestern tip of South Carolina. The larva of the species occurs in rapidly flowing warm water at a depth of about 15-65 cm. It may be associated with crevices in rocks covered by Riverweed in streams with otherwise sandy and gravelly substrate. The species may not have sensitivity to slight siltation or even general turbidity. The ventral abdominal protuberances possibly serve as adhesive structures for life in swift current<sup>35</sup>.

***Tsalia bernerii* (Allen & Edmunds, 1958)<sup>36</sup> (Ephemerellidae)**

This is a strictly southern Appalachian species, and it is the only species in its genus, representing an important component of regional and global phylogenetic diversity<sup>37</sup>. This species is known in South Carolina from only the Little River in Oconee County, with the most recent specimens taken in 1997<sup>2</sup>. Elsewhere, it is known from scattered locations in Georgia, North Carolina, Tennessee and Virginia<sup>3</sup>. This species has been considered to be vulnerable, and little is known about its specific ecological requirements<sup>12,33</sup>. The species sometimes is locally abundant in larger streams with densities of more than 200 individuals/square meter. It is found in mats of Riverweed and Watermoss (*Fontinalis* Hedwig, 1801), on rootmats and on rocks in riffle areas. Where it is found, the general stream substrate is composed of exposed bedrock, coarse pebbles and some cobbles. Water temperatures tend to be cool (ca. 12-15°C). The species has been collected from streams below impoundments. Subimagos emerged in early afternoon through early evening<sup>38</sup>.

**Critical habitat 3: slow or standing waters**

South Carolina's diverse wetlands are of particular conservation interest, because they have continued to demonstrate a net loss in the state, even with construction of new wetlands and mitigation efforts in place<sup>39</sup>. Each of the following mayfly species lives all or a significant part of its life in backwaters, overflows or slow edge-waters, especially during the later larval instars. Each species requires additional study in South Carolina, but until much more is known, each should be considered a species of concern in the state.

***Arthroplea bipunctata* (McDunnough, 1924)<sup>40</sup> (Arthropleidae)**

This Holarctic species is relatively widespread throughout Canada and the northeastern United States (including parts of the Upper Midwest), but it is primarily a far northern species<sup>41,42</sup>. The species has been listed as occurring in both North Carolina and South Carolina<sup>43,44</sup>, but the North Carolina reports have been disregarded recently<sup>3</sup>, probably due to lack of substantiating data<sup>10</sup>. Outside the Southeast, the nearest record is from northeast Ohio<sup>45</sup>. The only South Carolina record<sup>10</sup> is of a single larva from Boone Creek in Oconee County<sup>43,46</sup>. This represents the only

potentially verifiable Southeast data for the species<sup>3</sup>, but material has not been located for verification. Recently discovered North Carolina voucher material in the Purdue Entomological Research Collection proved to be a misidentification of *Cinygmula subaequalis* (Banks, 1914) (Heptageniidae)<sup>47</sup>, a heptageniid species with protruding maxillary palps that very superficially resembles *Arthroplea*. A similar misidentification might be the case for the South Carolina record of *Arthroplea*. If the South Carolina report represents a *bona fide* record of the species, then it is the extreme southern limit of its distribution. The genus is relatively easy to identify<sup>48</sup>. The larva occurs in stream overflow areas and backwaters with little or no flow, among coarse organic material<sup>49</sup>, a habitat often neglected during field surveys of aquatic macroinvertebrates.

#### ***Maccaffertium lenati* (McCafferty, 1990)<sup>50</sup> (Heptageniidae)**

This species is a strictly southeastern United States species<sup>50,51</sup>. In South Carolina, this species is known only from the western front of the piedmont, from a tributary of Watermelon Creek in Anderson County and from "Lake Isaquenna" in Pickens County, with the latter representing its most recent data, having been collected in 1987<sup>2</sup>. Elsewhere, it is known only from North Carolina, though from about 40 sites<sup>3,51</sup>. The species appears to favor transition areas on the edges of the piedmont ecological region and thus may demonstrate a relatively narrow set of physiochemical habitat requirements. In the appropriate streams, later larval instars are found on large rocks in slow current, either near the head of a riffle or near the banks. Adults emerge in middle May<sup>51</sup>.

#### ***Siphonurus decorus* Traver, 1932<sup>52</sup> (Siphonuridae)**

This southeastern United States Coastal Plains species has not been reported for over 35 years<sup>53</sup>. In South Carolina, this species is known only from Orangeburg County, based on adult material collected in April<sup>53</sup>; no other data have been available until now [Orangeburg, N. Edisto River, 20-IV-1955, Hynes & Berner, one female adult, housed in the Florida A&M University collection, Tallahassee, Florida]. Elsewhere, it is known only from two swamps in North Carolina<sup>52</sup>. The larva remains unknown, so specific habitat requirements are not determinable at this time. However, given the biology of the genus<sup>11</sup> and this particular species' tentative association with Coastal Plain swamps, it is likely that the larva, especially the later instars, will be found in standing or very slow flowing waters. Obvious threats include wetland habitat destruction and alteration. Concerted efforts should be made to verify the continued existence of this species.

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#### **References**

1. McCafferty WP. The gentle quest: 200 years in search of North American mayflies. In: Domínguez E, editor. Trends in Research in Ephemeroptera & Plecoptera. New York: Kluwer Academic / Plenum Publishers; 2001. p. 21-35.
2. McCafferty WP, Meyer MD. South Carolina mayflies (Ephemeroptera). Transactions of the American Entomological Society. 2008;134:283-335.
3. McCafferty WP, Lenat DR, Jacobus LM, Meyer MD. The mayflies (Ephemeroptera) of the southeastern United States. Transactions of the American Entomological Society. 2010;136:221-233.
4. McCafferty WP. Comparison of Old and New World *Acanthametropus* (Ephemeroptera: Acanthametropodidae) and other psammophilous mayflies. Entomological News. 1991;102:205-214.
5. Lillie RA. A survey of rare and endangered mayflies of selected rivers of Wisconsin. Wisconsin Department of Natural Resources, Research Report. 1995;170:1-23.
6. Peters WL, Peters JG. Adult life and emergence of *Dolania americana* in northwestern Florida (Ephemeroptera: Behningiidae). Internationale Revue der Gesamten Hydrobiologie. 1977;62:409-438.
7. McCafferty WP, Stark BP, Provonsha AP. Ephemeroptera, Plecoptera, and Odonata. In: Kosztarab M, Schaefer C, editors. Systematics of the North American Insects and Arachnids: Status and Needs. Blacksburg: Virginia Agricultural Experiment Station Information Series Number 90-1, Virginia Polytechnic Institute & State University; 1990. p. 43-58.
8. Burks BD. The mayflies, or Ephemeroptera, of Illinois. Bulletin of the Illinois Natural History Survey. 1953;26(1):1-216.
9. Edmunds GF, Jr., Allen RK, Peters WL. An annotated key to the nymphs of the families and subfamilies of mayflies (Ephemeroptera). University of Utah Biology Series. 1963;13:1-55.
10. McCafferty WP. Reporting species record data. Entomological News. 2001;111:311-312.
11. Edmunds GF, Jr., Jensen SL, Berner L. The mayflies of North and Central America. Minneapolis: University of Minnesota Press; 1976. 330 p.
12. Morse JC, Stark BP, McCafferty WP, Tennesen KJ. Southern Appalachian and other southeastern streams at risk: implications for mayflies, dragonflies and damselflies, stoneflies, and caddisflies. Pp. 17-42 In: Benz GW, Collins DE, editors. Aquatic Fauna in Peril: The Southeastern Perspective. Decatur, Georgia: Southeast Aquatic Research Institute, Lenz Design and Communications; 1997. p. 17-42.
13. US Fish and Wildlife Service. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species: proposed rule. Federal Register, part IV, US Department of the Interior 50 CFR part 17. 1994;59(219):58982-59028.
14. Lillie RA, Schmunde KL, Hilsenhoff WL. Rediscovery of *Acanthametropus pecatonica* in the western Great Lakes region (Ephemeroptera: Siphonuridae). Great Lakes Entomologist. 1987; 20: 85-86.
15. Lillie RA. New and additional distribution records for several rare mayflies (Ephemeroptera) in Wisconsin. Great Lakes Entomologist. 1992;25:135-136.
16. Edmunds GF, Jr., Koss RW. A review of the Acanthametropodinae with a description of a new genus. Pan-Pacific Entomologist. 1972;48:136-144.
17. Edmunds GF, Jr., Traver JR. The classification of the Ephemeroptera. I. Ephemeroidea: Behningiidae. Annals of the Entomological Society of America. 1959;52:43-51.
18. McCafferty WP. The American Sand Burrowing Mayfly *Dolania americana*. South Carolina Department of Natural Resources Comprehensive Wildlife Conservation Strategy: Species Descriptions. 2006; <http://www.dnr.sc.gov/cwcs/pdf/Mayfly.pdf>: pp. 1-6.

19. Jacobs WL. A new distributional record for the sand-burrowing mayfly *Dolania americana* (Ephemeroptera: Behningiidae). *Entomological News*. 1990;101:219-221.
20. Edmunds GF, Jr., Berner L, Traver JR. North American mayflies of the family Oligoneuriidae. *Annals of the Entomological Society of America*. 1958;51:375-382.
21. Pescador ML, Peters WL. A revision of the genus *Homoeoneuria* (Ephemeroptera: Oligoneuriidae). *Transactions of the American Entomological Society*. 1980;106:357-393.
22. Patrick R, Cairns J, Roback SW. An ecosystematic study of the fauna and flora of the Savannah River. *Proceedings of the Academy of Natural Sciences of Philadelphia*. 1967;118:109-407.
23. Brooks DW, Carlson PH, Cornell JF, Douglass HB, King EW, McCaskill VH, Morse JC, Skelton TE, Sponner J. Status report: Arthropoda other than Crustacea. In: Forsythe DM, Ezell WB, Jr., editors. *Proceedings of the First South Carolina Endangered Species Symposium*. 1979. p. 46-51.
24. Peters WL, Jones J. Historical and biological aspects of the Blackwater River in northwestern Florida. In: Peters WL, Peters JG, editors. *Proceedings of the first international conference on Ephemeroptera*. Leiden, Netherlands: E.J. Brill; 1973. p. 242-253.
25. Berner L, Pescador ML. *The mayflies of Florida*, revised edition. Tallahassee: University Presses of Florida; 1988. 416 p.
26. Hutchens, JJ, Jr., Wallace JB, Romaniszyn ED. Role of *Podostemum ceratophyllum* Michx. in structuring benthic macroinvertebrate assemblages in a southern Appalachian river. *Journal of the North American Benthological Society*. 2004;23:713-727.
27. Meijer W. A note on *Podostemum ceratophyllum* Michx., as an indicator of clean streams in and around the Appalachian Mountains. *Castanea*. 1976;41:319-324.
28. Argentina JE, Freeman MC, Freeman BJ. Predictors of occurrence of the aquatic macrophyte *Podostemum ceratophyllum* in a Southern Appalachian River. *Southeastern Naturalist*. 2010;9:465-476.
29. Waltz RD, McCafferty WP, Kennedy JH. *Barbaetis*: A new genus of eastern Nearctic mayflies (Ephemeroptera: Baetidae). *Great Lakes Entomologist*. 1985;18:161-165.
30. Beaty SR. *The Ephemeroptera of North Carolina: A biologist's handbook with standard taxonomic effort levels*. Raleigh: Biological Assessment Unit, Division of Water Quality, North Carolina Department of Environment and Natural Resources; 2011. p. 57.
31. Kondratieff BC, Kirchner RF. Mayflies, Class Insecta: Order Ephemeroptera, subphylum Tracheata. In: Terwilliger K, editor. *Virginia's Endangered Species*. Blacksburg: Proceedings of a Symposium. McDonald and Woodward Publishing Company; 1991. p. 194-197.
32. Lenat DR, Penrose DL. New distribution records for North Carolina macroinvertebrates. *Entomological News*. 1987;98:67-73.
33. Morse JC, Stark BP, McCafferty WP. Southern Appalachian streams at risk: implications for mayflies, stoneflies, caddisflies, and other aquatic biota. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 1993;3:293-303.
34. North Carolina Department of Environment and Natural Resources (NCDENR). *Natural Heritage Program List of the Rare Animal Species of North Carolina*. Raleigh: NCDENR, Division of Natural Resource Planning and Conservation; 2010. p. 160.
35. Muller-Liebenau I. *Rheobaetis*: a new genus from Georgia (Ephemeroptera: Baetidae). *Annals of the Entomological Society of America*. 1974;67:555-567.
36. Allen RK, Edmunds GF, Jr. A new species of *Ephemerella* from Georgia (Ephemeroptera: Ephemerellidae). *Journal of the Kansas Entomological Society*. 1958;31:222-224.
37. Jacobus LM, McCafferty WP. Revision of Ephemerellidae genera. *Transactions of the American Entomological Society*. 1958;134:185-274.
38. Kondratieff BC, Foster JWS III, Voshell JR, Jr. Description of the adult of *Ephemerella beneri* Allen and Edmunds (Ephemeroptera: Ephemerellidae) with biological notes. *Proceedings of the Entomological Society of Washington*. 1981;83:300-303.
39. Dahl TE. *South Carolina's wetlands: status and trends, 1982-1989*. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service; 1999. p. 58.
40. McDunnough J. New Ephemeridae from New England. *Occasional Papers of the Boston Society of Natural History*. 1924;8:73-76.
41. Burian SK, Gibbs KE. *Mayflies of Maine: An annotated faunal list*. Maine Agricultural Experiment Station Technical Bulletin. 1991;142:1-109.
42. Randolph RP, McCafferty WP. Diversity and distribution of the mayflies (Ephemeroptera) of Illinois, Indiana, Kentucky, Michigan, Ohio, and Wisconsin. *Ohio Biological Survey Bulletin NS*. 1998;13(1):VII + 188.
43. Unzicker JD, Carlson PH. Ephemeroptera. In: Brigham AR, Brigham WU, Gnilka, editors. *Aquatic Insects and Oligochaetes of North and South Carolina*. Mahomet: Midwest Aquatic Enterprises; 1982. p. 3.1-3.97.
44. Pescador ML, Lenat DR, Hubbard MD. Mayflies (Ephemeroptera) of North Carolina and South Carolina: an update. *Florida Entomologist*. 1999;82:316-332.
45. McElravy EP, Foote BA. Range extension and new state record for *Arthroplea bipunctata* (McDunnough) (Ephemeroptera: Heptageniidae). *Annals of the Entomological Society of America*. 1975;68: 310.
46. Schultz DA, Tebo LB, Jr.. Boone Creek Oil Spill. Athens: USEPA, Surveillance Analysis Division; 1973. p. 37.
47. Banks N. New neuropteroid insects, native and exotic. *Proceedings of the Academy of Natural Sciences of Philadelphia*. 1914;66:608-632.
48. Wang T-Q; McCafferty WP. Relationships of the Arthropleidae, Heptageniidae, and Pseudironidae (Ephemeroptera: Heptagenioidea). *Entomological News*. 1995;106(5):251-256.
49. Myers LW, Jacobus LM, Kondratieff BC. *Insecta, Ephemeroptera: New and additional records from New York (U.S.A.)*. *Check List*. 2008;4:415-423.
50. McCafferty WP. A new species of *Stenonema* (Ephemeroptera: Heptageniidae) from North Carolina. *Proceedings of the Entomological Society of Washington*. 1990;92:760-764.
51. Kondratieff BC, Zuellich RE, Lenat DR. Description of the adults of *Maccaffertium lenati* (Ephemeroptera, Heptageniidae), notes on its ecology and distribution, and a new North Carolina record for *Isonychia arida* (Ephemeroptera: Isonychiidae). *Proceedings of the Entomological Society of Washington*. 2008;108:995-997.
52. Traver, JR. *Mayflies of North Carolina*. *Journal of the Elisha Mitchell Scientific Society*. 1932;47(1):85-161; 47(2):163-236.
53. Berner L. Distributional patterns of Southeastern mayflies (Ephemeroptera). *Bulletin of the Florida State Museum, Biological Sciences*. 1977;22:1-56.