Southern Appalachian and Other SoutheasternStreams at Risk: Implications for Mayflies, Dragonflies and Damselflies, Stoneflies, and Caddisflies

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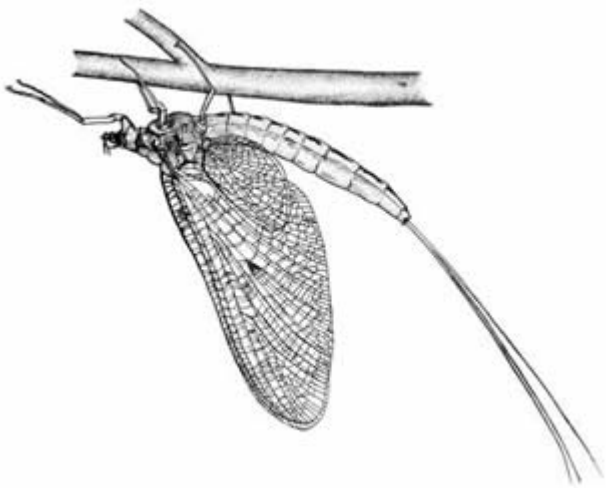

The regional focus of this paper is the southern Appalachian Mountains. The aquatic insect fauna of the southern Appalachians is especially distinctive and generally appears to be most threatened among aquatic insects. The Piedmont, Sandhills, Coastal Plain, and Interior Highland regions of the Southeast also are interesting, with several endemic species of freshwater insects known in these other areas.

The taxonomic focus of this paper is the four orders of aquatic insects containing the mayflies, dragonflies and damselflies, stoneflies, and caddisflies. There are many other orders of insects with freshwater representatives, including a few that are exclusively aquatic. However, the mayflies, stoneflies, and caddisflies (Ephemeroptera, Plecoptera, and Trichoptera, or EPT) have generally long been considered especially sensitive to pollution and disturbance and thus are now used in most developed countries to help indicate the presence of pollution. These three orders of insects are also of special interest to those involved with sport fishing because they often serve as the primary food for many species of game fish. An ability to fabricate or "tie" imitations of these insects and to cast them in such a way as to emulate natural insect behavior is considered the mark of an excellent trout angler. Unlike the secretive adults of the EPT orders, however, the adults of dragonflies and damselflies, or the Odonata, are large and colorful insects that have attracted popular attention. Consequently, we probably know more about the biology and distribution of Odonata species than of those of the three EPT orders. Collectively these four orders, whose approximately 3,000 North American species constitute about 26 percent of the aquatic insect species on the continent (Table 1), are in many ways representative of the situation in the remaining groups of aquatic insects.

The objectives of this chapter are to consider:

- the southeastern and southern Appalachian insect fauna of mayflies, dragonflies and damselflies, stoneflies, and caddisflies;
- the structural features that account for these species' uniqueness in the southern Appalachians;
- the historical changes that humans and other forces have made in the streams and rivers of the region; and
- the impacts of these environmental changes on the region's aquatic insect fauna, again paying particular attention to species of Ephemeroptera, Odonata, Plecoptera, and Trichoptera.

Table 1. Approximate numbers of known aquatic insect species of the world, North America north of Mexico, and the United States of America.

Taxon	**World**[1]	**North America**	**Southeastern United States**
Ephemeroptera - mayflies	2,000	611	238
Odonata - dragon/damselflies	4,870	500	241
Plecoptera - stoneflies	2,000	595	189
Trichoptera - caddisflies	10,000	1,369	544
All Other Aquatic Insects[1]	45,000	8,000	3,000
Total Species[1]	63,870	11,053	4,212

[1] Approximate number of species reported.

The Fauna

Collectively there are about 11,053 species of aquatic insects in America north of Mexico. Of these, 611 species are mayflies, about 500 species are dragonflies and damselflies, 595 are stoneflies, and 1,369 are caddisflies (Table 1). About 40 percent of the North American aquatic insect fauna is represented in the Southeast, a region occupying only about six percent of the continental area north of Mexico.

The mayflies, or Ephemeroptera, are represented in the Southeast by 238 species, belonging to 63 genera in 16 families, constituting 39 percent of the continental mayfly fauna. Eighty-eight mayfly species (14 percent of the Nearctic species) are endemic to the Southeast. The larvae of these insects occur in a wide range of habitats, including both lentic and lotic environments, with most species intolerant of organic pollution, toxicants, and siltation. Highest mayfly diversity is found in rocky bottomed headwater streams (second to third order). Mayflies spend most of their lives as larvae, emerging as alate forms (subimagoes and adults) at particular times of the year and particular times of day or night, living for only a few hours to a few days during which they mate and lay eggs. Larvae of most species feed by collecting, scraping or brushing detritus and algae from rocks and other substrates, often filtering it through the fine hairs associated with their mouthparts. Mayflies require space among the stream-bottom rocks for feeding and for harborage. Some of the larger species burrow in silt, clay, or sand.

The dragonflies and damselflies, or Odonata, are represented in the Southeast by 241 species, belonging to 48 genera in ten families, constituting 48 percent of the continental dragonfly and damselfly fauna. Forty-two Odonata species (17 percent of the Nearctic species) are endemic to the Southeast. The larvae of these insects also occur in a wide variety of mostly lentic habitats, either burrowing just under the surface of the sediments, sprawling in sediment or detritus, or climbing vascular plants. They are all predators that have a uniquely elaborated lower lip that is elbowed beneath the head when at rest and capable of capturing prey when extended at very high speed. Larvae are so intimately associated with stream and pond bottoms that disturbance of the substrate or increase of fine silt seriously impacts the ability of these insects to survive. Adults typically fly during the daylight hours and hunt by sight, contributing to their familiarity among casual naturalists.

The stoneflies, or Plecoptera, are represented in the Southeast by 189 species, belonging to 40 genera in nine families, constituting 32 percent of the continental stonefly fauna. Forty-four species (7.4 percent of the Nearctic species) are endemic to the Southeast. Stonefly larvae occur mostly in streams, with highest diversity in rocky headwater streams of second to third order, mostly either scurrying about among the rocks looking for prey or in accumulations of dead leaves and sticks where they shred these materials for food. They usually emerge into adulthood after crawling from the water at the shore or on a rock or log protruding from the water. The adults are secretive, poor flyers, and seldom seen in large numbers except near their stream habitats, with much of their adult activity occurring after dark. Like those of mayflies, stonefly adults also do not live long before mating, laying eggs, and dying, occasionally feeding on epiphytic algae or young leaves and buds of riparian vegetation. Plecoptera are especially sensitive to sedimentation and organic pollution, quickly disappearing from streams where these problems exist.

The caddisflies, or Trichoptera, are represented in the Southeast by 544 species, belonging to 78 genera in 22 families, constituting 40 percent of the continental caddisfly fauna. One hundred sixty-eight species (12 percent of the Nearctic species) are endemic to the Southeast. Caddisfly larvae occur in a wide range of habitats, with highest diversity in rocky headwater streams of second to fourth order. They exhibit the widest range of behaviors of the insect groups discussed here and can be found burrowing in sediments, sprawling or clinging on substrates, or swimming in quieter waters. Some species are free-living, others build silken retreats which may have special nets to filter fine food particles from the flowing water, and others construct cases in which they live and which they drag over the bottom as they move. Caddisflies feed by shredding dead leaves, collecting detritus and algae and microcrustaceans from the bottom, filtering food items from the water column, scraping algae from stable solid substrates, piercing individual cells of filamentous algae, and preying on other insects. To facilitate pupation, larvae either construct a pupation chamber or attach the larval case to something stable and seal it. After a few weeks, they swim to the surface of the water to emerge as adults. Adults live for several days to several weeks, imbibing liquids for sustenance, mating and eventually laying their eggs above, on, or in the water. Caddisflies have a wider range of pollution tolerances than some of the other aquatic insect groups, with some being very pollution sensitive and others being able to withstand modest environmental insults. Like the other insect orders discussed here, caddisflies are generally very dependent on an unsilted stream bottom because they require spaces among rocks for shelter and stable surfaces for grazing and attaching their retreats and filter nets.

Structural Features

The southern Appalachian Mountains apparently have held a special fascination for people in North America for thousands of years. The relatively mild climate of these mountains, their rich plant and animal life, and their abundant water have encouraged settlement by Native Americans and the descendants of European colonists. The rugged terrain and dense vegetation historically discouraged travel, large-scale agriculture, and heavy industrialization. In recent years, however, the spectacular vistas have attracted tourists and encouraged development aimed at the vacation and retirement markets.

For purposes of this chapter, we define the Southeast as the states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. We recognize the southern Appalachian Mountains as the region covered by the Blue Ridge and the Ridge and Valley physiographic provinces from Maryland and West Virginia southward into Georgia and Alabama. The Appalachian Mountains are bordered on the northwest by the Allegheny and Cumberland Plateau region. They are bordered on the southeast by

the wide Piedmont region, from which the Mountains are separated by the Blue Ridge Escarpment, sometimes dropping 300 m (984 feet) or more on an average 45 degree angle. Streams crossing the Blue Ridge Escarpment often produce spectacular waterfalls. Elevations in the Blue Ridge region generally range between 600-1,000 m (1,969-3,281 feet); those in the Ridge and Valley region are generally between 300-900 m (984-2,953 feet) (Isphording and Fitzpatrick, 1992).

Streams of the southern Appalachians are unique for several reasons. These mountains were never glaciated. Therefore, the saprolitic ultisol and inceptisol soils are generally residual and not sedimentary; that is, they weathered chemically in place. Soils at the lower elevations frequently are deep and highly structured vertically, with a conspicuous sandy or loamy horizon above a loamy or clayey horizon. Soils at higher elevations have undergone less alteration of the parent rock. These are young soils lacking much clay accumulation (Isphording and Fitzpatrick, 1992). The fact that the southern Appalachians were not glaciated also means that many species, including aquatic insects, evolved in place; while others moved south with the glaciers and were left as isolated populations with high speciation potential when the ice receded (Ross and Ricker, 1971).

The southern Appalachian Mountains have relatively mild winters and summers. This warmer climate means that there is greater biological activity than is found at higher latitudes. Therefore, at both high and low elevations, although the vegetation is dense, the surface organic layer is shallow because of rapid decay on the generally humid, warm, temperate forest floor. Concurrently, a much smaller portion of the southeastern caddisfly fauna, for example, consists of shredding detritivores, such as Limnephilidae, than is found in other parts of the continent (Hamilton and Morse, 1990). During the Pleistocene Epoch, the climate was cooler and drier, probably resulting in fewer streams with less flow. Such conditions would have created isolated aquatic insect populations and thus facilitated higher rates of species diversification.

Shade associated with vegetation is seasonal throughout the southern Appalachians, and this limits autochthonous primary production in headwater streams during April through October. Thus, most of the nutrient energy for the heterotrophic fauna enters the headwater streams as allochthonous leaf and wood debris (Hornick et al., 1981; Webster et al., 1983), averaging about 400 g dry mass per m2 per year (1.3 ounces dry mass per square foot per year) in the southern Appalachians (Bray and Gorham, 1964).

Precipitation is relatively high in the southern Appalachians, averaging 100-200 cm per year (40-80 inches per year; Wallace et al., 1992). Consequently, most southern Appalachian streams are permanent, with small seeps and springs occurring frequently. Because infiltration through the topsoil exceeds rainfall in

undisturbed forests of the southern Appalachians, there is little overland flow and consequently little movement of sediments. When topsoils are removed or compacted (crushing their macropores), surface runoff increases and sediment is transported to streams, especially in mountainous areas with greater topographic relief.

Streams of the southern Appalachians have high natural structural complexity, with rocks, some sand, large woody debris, and leaf packs providing cover and protection from predators and scouring; attachment surfaces for periphyton, sprawlers, and clingers; means for entrainment of organic and inorganic matter; complicated flow patterns; and sediment heterogeneity.

These streams also have high physicochemical variability, especially in mid-order reaches (third to fifth order streams). This variability is the result of two general features: (a) distinctive seasons that affect temperature, flow regimes, and sunlight penetration, and (b) irregularities of flow caused by heavy storms at all times of year that affect temperature, current velocity, and nutrient pulses. Thus, abiotic factors may control the freshwater communities here more than biotic factors such as competition and predation (Allan, 1983; Peckarsky, 1983).

Together, the aforementioned major factors, and probably others, have resulted in some of the highest aquatic insect species diversity and one of the highest concentrations of endemic species on the continent, especially for Ephemeroptera, Plecoptera, and Trichoptera (Holt et al., 1969). For example, 72, 89, and 73 percent of the species of mayflies, stoneflies, and caddisflies, respectively, in the two Carolinas occur in the southern Appalachian Mountains (Table 2), with 31, 36, and 38 percent of them occurring there exclusively (Brigham et al., 1982). Usually dwelling in more slowly moving water, dragonflies and damselflies have relatively fewer endemic species in these mountains (14 percent, Table 2). Among all 1,653 caddisfly species known in North America (including Greenland and Mexico; Morse, 1993), 104 (six percent) are endemic to the Eastern Highlands, defined as the Cumberland Plateau, Appalachian plateaus, Appalachian Mountains, and Piedmont (Hamilton and Morse, 1990), and 63 species (four percent) are endemic to the southern Appalachian Mountains.

Table 2. Number and percent (in parentheses) of species of mayflies (Ephemeroptera), dragonflies and damselflies (Odonata), stoneflies (Plectoptera), and caddisflies (Trichoptera) in the mountains and other physiographic regions of North and South Carolina (Brigham et al., 1982).

Taxon	Mountains Only	Mountains & Other Areas	Total In Mountains	Non-mountainous Areas Only	Total in NC & SC

Ephemeroptera	54 (31)	70 (41)	124 (72)	49 (28)	173 (100)
Odonata	26 (14)	92 (51)	118 (65)	63 (35)	181 (100)
Plecoptera	42 (36)	63 (53)	105 (89)	13 (11)	118 (100)
Trichoptera	104 (38)	96 (35)	200 (73)	74 (27)	274 (100)
TOTAL	226 (30)	321 (43)	547 (73)	199 (27)	746 (100)

Human Impacts

What are the historical factors that have influenced the southern Appalachian streams and their faunas? Their aboriginal inhabitants, primarily Cherokee Indians, used fire extensively as an aid in hunting, for clearing cropland, and for maintaining habitats for berries, deer, and turkey (Hughes, 1983). Beaver built millions of dams on small order streams which slowed flow rates, opened canopies, and provided habitat for many species of freshwater plants and animals. Beaver were essentially eliminated from the southern Appalachians by the late 1700s (Hackney and Adams, 1992). Early European settlers practiced slash-and-burn agriculture and traveled on dirt roads that forded the many streams in the region, causing unknown amounts of sedimentation. They also built mill ponds, drained swamps, and snagged and dredged streams to make them navigable.

The United States Army Corps of Engineers, the Tennessee Valley Authority, and electrical power companies have built many reservoirs throughout the Southeast, especially during the past 50 years. Most southeastern reservoirs have been built in the upland regions, including many in the southern Appalachian Mountains (Soballe et al., 1992). Other lentic habitats have been created on private lands as generally small ponds, mostly for controlling erosion, irrigating crops, watering cattle, fishing, and swimming; their significance lies in their sheer

number (Menzel and Cooper, 1992). Thus, many streams in the southern Appalachians now have small ponds in their headwaters and huge reservoirs in their lower reaches. Of course, these structures affect flow rates, oxygen levels, and temperatures; they accelerate phytoplankton and macrophyte production rates and obstruct movements of fish. Because the Southeast had few natural lakes, many of the species inhabiting these recently constructed reservoirs, at least among caddisflies, tend to be generalists that apparently have invaded them from slowing moving streams (Hudson et al., 1981). At the same time, those collector-filterer species that can tolerate highly variable flow and temperature regimes and that thrive especially on planktonic organisms have proliferated below the dams.

Although the cutting of trees in the southern Appalachians has continued for a long time, large-scale removal of wood began in the late 1800s, after most of the primary forests of the Northeast and Midwest had been removed. Deforestation continued for about 45 years, resulting in severe erosion and sedimentation (Trimble, 1975; Meade, 1976). Beginning in 1925, professional foresters of the U.S. Forest Service began providing protection from fire and heavy cutting. Initially, they favored selection management, maintaining uneven-aged forests. However, this type of management was difficult because the small canopy openings did not permit regeneration of desirable species, and the frequent re-entry into the forests to cut selected trees caused continual sources of sedimentation in the streams. Clearcutting became standard practice on national forest lands by about 1965 and continues to the present.

Another major alteration of the flora was the loss of the co-dominant tree species in the southern Appalachians during the first half of this century. Most mature specimens of the American chestnut (*Castanea dentata* [Marshall]) were killed by the chestnut blight fungus (*Cryphonectria parasitica* [Murrill and Barr]), introduced from Asia in 1904. The chestnuts were replaced mostly by various species of oaks. Because of differences in processing rates of dead leaves among these tree species and resulting differences in insect growth rates, adult body mass, and fecundity, some evidence suggests that insect faunas in headwater streams in the southern Appalachians may have experienced subtle changes (Smock and MacGregor, 1988). Shredding detritivore species among the stoneflies and caddisflies and some other insect groups probably were especially affected.

Changes brought about by these activities, especially the heavy cutting adjacent to the streams that was common logging practice at the turn of the century, have reduced the amount of large woody debris currently in southern Appalachian streams. Because new stands regenerated in the cutover riparian zones, the sources of large woody debris (i.e., large, old trees) declined and will remain low for decades (Hedman, 1992; Hedman and Van Lear, 1994; Hedman et al., 1996).

Opening of the canopies has allowed the increase of *Rhododendron* understory, which now outcompetes shoots of other species and which provides poor quality allochthonous input for macroinvertebrate shredders (D. H. Van Lear, Clemson University, pers. comm.).

With this historical background, what are the forces presently influencing the quality of stream habitats in the southern Appalachian Mountains? Streams in the otherwise well-protected Great Smoky Mountains National Park are threatened by acid precipitation. Both acid precipitation and outbreaks of forest pests (mostly foreign invaders) weaken and kill trees and other vegetation in the stream riparian zones (C. R. Parker, U.S. Department of the Interior, National Park Service, pers. comm.), reducing allochthonous nutrient inputs.

Agriculture in the region is often the primary nonpoint-source of sedimentation, pesticides, and excess nutrients. Sedimentation apparently causes most of the damage in stream systems, and effective erosion control practices can help prevent it (Lenat, 1984).

Trout farms are a serious concern. Because of their need for large amounts of cold water, they are usually built on outstanding resource waterways, often in a succession of private farms, each contributing a heavy load of organic nutrients.

Residential development, especially for tourism and retirement, is another major problem for stream biotas. Residential developments are generally in "the nicest places" (e.g., beside streams) and are generally associated with golf courses kept "pretty" with pesticides and fertilizers. Housing starts in the southern Appalachian Mountains of Georgia, North Carolina, South Carolina, and Tennessee declined somewhat in the late 1980s, probably because of downturns in the economy, from a high of 9,500 in 1984 to a low of 5,600 in 1990. With economic improvements we are likely to see a significant rise in housing starts, and with them associated declines in stream water quality.

Sedimentation problems associated with forestry operations are diminishing in the southern Appalachians. Clearcuts average only about ten ha (25 acres) in Appalachian national forests, covering much smaller tracts than in the Pacific Northwest for example. Cleared areas are occasionally burned of slash and replanted, and the roads and staging areas are seeded with grasses and legumes. The use of 30-160 m (98-525 foot) buffer strips (depending on the slope of the land) and other Best Management Practices, especially on logging roads and skid trails (which ordinarily provide about 90 percent of the forestry-associated sediment in streams), has significantly reduced the sediment input in national forest lands. However, much forest land is in private ownership, and in South Carolina, for example, landowners are accepting the South Carolina Forestry Commission (SCFC) Best Management Practices, albeit more slowly than such practices have been instituted on national forest lands (85 percent compliance in

South Carolina in 1992) (D.H. Van Lear, Clemson University and T.O. Adams, SCFC, both pers. comm.).

Industrial effluent provides point sources of pollution that can harm streams. Reducing or stopping these problems is often complicated by legal, political, and economic circumstances, with regulators, private citizens, lawmakers, employers, and employees often at odds. The wheels are turning very slowly to rectify existing legal uncertainties associated with industrial effluent. For example, progress is being made to reduce damage caused by Champion Paper Company effluent into the Pigeon River in western North Carolina (D. R. Lenat, North Carolina Division of Environmental Management, pers. comm.).

Impacts On Mayflies, Dragonflies And Damselflies, Stoneflies, And Caddisflies

What have been the impacts of human activity on the aquatic insects of the southern Appalachians? For the most part we do not know. As we indicated above, the most serious sedimentation problems in the region apparently occurred with deforestation during the early part of this century, before much was known about the biota of these streams. Apart from a few descriptions by Nathan Banks (stoneflies and caddisflies, mostly during 1905-1914; e.g., Banks 1905, 1914) and Traver (mayflies during 1932-1937; e.g., Needham et al., 1935; Traver, 1937), extensive studies of the aquatic insects of the region were undertaken by staff of the Illinois Natural History Survey in the 1930s, examining the region's mayflies (Burks, 1953), stoneflies (Frison, 1937, 1942), and caddisflies (e.g., Ross, 1938). However, faunistic and ecological knowledge was gathered in such a sporadic manner in those early years that few general statements can be made about modern changes in the stream biota. The work by Brigham et al. (1982) provided keys for all the southeastern genera and many of the southeastern species of aquatic insects and oligochaetes, along with discussions of their habits and life histories.

We consider 19 species of mayflies, seven species of dragonflies, 17 species of stoneflies, and 38 species of caddisflies to be probably rare and vulnerable to extirpation at present in the southern Appalachian Mountains (Tables 3-6). Because of taxonomic problems and the fact that some habitats, such as small streams and seeps, have been poorly explored, the included species should be understood as probable examples of the many rare and vulnerable species in the southern Appalachians rather than as members of definitive lists. The United States Fish and Wildlife Service (1994) cited one of these mayfly species, all seven of these dragonfly species, and ten of these caddisfly species in their Category 2 (now Federal Species of Concern), for which further information is needed in order to justify listing them as endangered or threatened. Whether these particular 81 species have always been rare or whether there were at one time

other species that were then rare and now extinct cannot be determined. Some of these species have not been collected since the 1930s and 40s and may now be extirpated, such as the caddisfly *Agapetus vireo* Ross, and the stoneflies *Acroneuria arida* (Hagen) and *Amphinemura mockfordi* (Ricker). Furthermore, one dragonfly, *Ophiogomphus edmundo* Needham, is known only from two males collected in the late 1800s at some unknown location in North Carolina, and the distinctive mayfly *Isonychia diversa* Traver is known from only a single male taken in Knoxville, Tennessee, in 1916.

Many of these rare species are known from only one or a few locations with pea-size gravel or in springbrooks and seepage areas. Of course, species requiring pea-gravel are susceptible to sedimentation problems. For example, one of us (BPS) has observed the disappearance of the stoneflies *Malirekus hastatus* (Banks), *Yugus bulbosus* (Frison), and *Remenus bilobatus* (Needham and Claassen) from Scaly Creek, near the Scaly Mountain community in Macon County, North Carolina, where development of summer homes has greatly increased stream run-off and turbidity. In other locations, rock outcrop inhabitants such as the caddisfly *Pseudogoera singularis* Carpenter and *Heterocloeon* sp. mayflies have been observed (by JCM) as having disappeared as a result of clearcutting to the stream banks. Another riffle-dwelling mayfly species, *Serratella spiculosa* Berner and Allen, is listed by the U.S. Fish and Wildlife Service (1994) as not having been reported in 30 years. Drought, acid precipitation, or development may impair or eliminate the small "island" populations of the spring-habitat species such as *Ceratopsyche etnieri* (Schuster and Talak) and *Hydroptila decia* Etnier and Way. These two caddisfly species are among those listed in the United States Fish and Wildlife Service's (1994) Category 2. The stoneflies *Beloneuria georgiana* (Banks), *Megaleuctra williamsae* Hanson, and *Oconoperla innubila* (Needham and Claassen) are also vulnerable spring-inhabiting species. The stonefly *Zapada chila* (Ricker) may also be threatened by acid precipitation because its habitat is only at high elevations in the Appalachians.

Table 3. Rare and vulnerable Ephemeroptera of the southern Appalachian Mountains.

Family: *Species*	- Species Notes
Baetidae:	
Barbaetis benfieldi Kennedy	- medium to large streams with pea-gravel and clean water.
Callibaetis	- rare in scattered southern localities, including mountain

pretiosus Banks	stream pools.
Heterocloeon petersi (Müller-Liebenau)	- only known from a few well-oxygenated southern Appalachian streams.
Procloeon quaesitum (McDunnough)	- mountain streams with pea-gravel substrate.
P. rivulare (Traver)	- requires very high water quality.
Ephemerellidae:	
Drunella longicornis Traver	- widespread, clean-water, riffle species.
D. waya Traver	- somewhat rare species on sand-gravel substrates with moderate current.
Ephemerella berneri Allen & Edmunds	- rare southeastern species with little known of its ecological requirements.
E. floripara McCafferty	- rare species in headwater streams 200-800 m elevation with mixture of stones and sand or bedrock and sand substrate and with moderate to somewhat stronger currents.
Serratella carolina Berner & Allen	- rare, southeastern riffle species.
S. spiculosa Berner & Allen	- "spiculose serratellan mayfly," rare, southeastern riffle species; Category 2 of U.S. Fish and Wildlife Service (1994), not reported since 1963.
Ephemeridae:	

Litobrancha recurvata (Morgan)	- mainly a northeastern species, somewhat rare in Southeast, requiring small, clean, cold-water streams with silt/marl substrate.
Heptageniidae:	
Iron subpallidus Traver, *Rhithrogena amica* Traver, *R. exelis* Traver, *R. fuscifrons* Traver, *R. rubicunda* Traver	- all relatively rare in streams with moderate to fast current and mixed substrate, feed on periphyton that require some open canopy; some may be synonyms of other species.
Stenonema carlsoni Lewis	- known only from streams with very high water quality.
Isonychiidae:	
Isonychia georgiae McDunnough	- rare in moderately large streams with a variety of stream conditions.

Table 4. Rare and vulnerable Odonata of the southern Appalachian Mountains.

Family: *Species*	-Species Notes
Gomphidae:	
Gomphus (Stenogomphurus) consanguis (Selys)	- "Cherokee clubtail," known from only 6 or 7 localities in very small populations in AL, GA, NC, TN, and VA; Category 2 of U.S. Fish and Wildlife Service (1994).
Gomphus	- known from only 8 or 9 localities in AL, GA, MD, NC, and

(Gomphus) parvidens Currie	VA; subspecies G. p. carolinus Carle, "sandhills clubtail, is known from about 7 localities in southeastern Piedmont and Sandhills in small populations and is in Category 2 of U.S. Fish and Wildlife Service (1994).
Gomphus (Gomphurus) septima Westfall	- "Septima's clubtail, known from only 4 or 5 localities; AL population has not been seen since about 1940; unpublished TN record is based on 1 male; there are only 1 or 2 well-established populations in NC; Category 2 of U.S. Fish and Wildlife Service (1994).
Ophiogomphus edmundo Needham	"Edmund's snaketail," known from 2 males collected in late 1800s in NC; Category 2 of U.S. Fish and Wildlife Service (1994).
O. incurvatus alleghaniensis Carle	"Alleghany snaketail, some questions exist regarding taxonomic status of this animal, some believing that it is a distinct species; few known populations are small, except for 1 healthy population in Smoky Mountains; adult stage is difficult to find; Category 2 of U.S. Fish and Wildlife Service (1994).
Stylurus townesi Gloyd	"bronze clubtail, known from 4 localities; TN record is based on 1 male; the only large population is in northwestern FL; Category 2 of U.S. Fish and Wildlife Service (1994).
Macromiidae:	
Macromia margarita Westfall	"Margarita river skimmer, known from only 6 or 7 localities, all known populations small; Category 2 of U.S. Fish and Wildlife Service (1994).

Rare Species Elsewhere In The Southeast

The freshwater habitats of the southeastern Piedmont, Coastal Plain, and Interior Highlands also are home to aquatic insects in peril. We recognize 11 species of mayflies, 17 species of dragonflies and damselflies, 17 species of stoneflies, and 28 species of caddisflies as being very rare, known from only one or a very few locations, and thus quite susceptible to extirpation (Tables 7-10).

Table 5. Rare and vulnerable Plecoptera of the southern Appalachian Mountains.

Family: *Species*	-Species Notes
Capniidae:	
Allocapnia brooksi Ross	- known from 2 streams in Hawkins and Sevier counties, TN.
A. fumosa Ross	- known from five streams at high elevations in Haywood County, NC; Sevier County, TN; and near Mt. Rogers, VA.
Leuctridae:	
Megaleuctra williamsae Hanson	- known from scattered localities around Great Smoky Mountains National Park, TN; and 1 locality each in NC, SC, and VA.
Nemouridae:	
Amphinemura mockfordi (Ricker)	- known from 2 localities at Monteagle, TN; last seen in 1938.
Zapada chila (Ricker)	- known from only a short stretch of 1 stream near Newfound Gap, TN.
Taeniopterygidae:	
Strophopteryx inaya Ricker & Ross	- known from 2 localities, 1 each in Jackson and McDowell counties, NC.
Taeniopteryx nelsoni Kondratieff & Kirchner	- known only from Mount Rogers area of VA.
Chloroperlidae:	
Sweltsa	- until recently known from 1 locality in Great Smoky

urticae (Ricker)	Mountains National Park and reported from VA without specific locality; Kondratieff (Colorado State University, pers. comm.) reports the species is quite common in spring seeps in Haywood and Macon counties, NC.
Peltoperlidae:	
Tallaperla elisa Stark	- known from 1 locality in Great Smoky Mountains National Park.
Perlidae:	
Acroneuria petersi Stark & Gaufin	- known from 1 locality in GA and 1 in Great Smoky Mountains National Park, TN.
A. arida (Hagen)	- reported from GA, NC, NJ, PA, and TN, but there are no recent GA, NC, or TN records; most records are from 1930s.
Beloneuria georgiana (Banks)	- fairly common in a restricted area of NC and GA, but at low densities; probably a top carnivore in small spring seepage areas.
B. stewarti Stark & Szczytko	- fairly common in low elevation seeps of GA, NC, SC, and TN, but at low densities.
Perlodidae:	
Diploperla morgani Kondratieff & Voshell	- known from several localities in southwestern VA and adjacent areas of WV and NC.
Isoperla bellona Banks	- known from Black Mountain, NC, and from GA, no recent sightings.
I. distincta Nelson	- known from 2 localities in TN and 1 in NC.
Oconoperla innubila	- known from 8 scattered spring seepage areas in NC, SC, and TN.

(Needham & Claassen)	

Constraints On Knowledge Of Aquatic Insect Systematics And Biology

Although we do not know the specific habitat requirements of most of these species, the probability that they are very limited in distribution suggests that some features of their environments are holding their populations in check, whether these features are anthropogenic or natural. Obviously, we do not know very much about the biology of rare aquatic insects in the Southeast, although there can be little doubt that many are in peril. Perhaps as much or more for the insects as for any other taxonomic group reported on in this volume, knowledge of the very existence of these tiny, cryptic, yet fascinating creatures, let alone their distribution, ecology, life history, and habitat requirements is sorely lacking. We are still finding new species every year in the Southeast, and commonly adding range extensions to species that have already been described. Part of the difficulty, of course, is their small size and cryptic habits. Insects change form dramatically during their development, and their species can be identified usually only in the adult form that lives for just a few hours to a few days each year. Furthermore, the taxonomy of aquatic insects usually relies heavily on characteristics possessed only by males of each species. Rearing and associating the females and the immature stages with their respective males is a very time-consuming task that is naturally lagging far behind the study of the systematics of the males. But it is those very studies that are needed in order to allow ecologists to investigate life histories and habitat requirements.

On top of all of the above, the incredible diversity of the entomofauna, representing about 85 percent of the plant and animal species of the world, makes for a very huge task for the practicing insect systematists, of whom there are fewer each year to provide scientific support for the growing interest in biodiversity protection. Unlike the situation associated with various macrobiota, most species of insects can be identified by only a handful of people in the world, each of whom are experts regarding only specific taxa. It is difficult for these experts to carry this workload alone. They need the support and encouragement of a much larger group of interested persons such as natural historians, conservationists, scientists, and other concerned citizens, all of whom depend on systematics research conclusions. Systematists need the political and financial support of the wider constituency to maintain collections of living and preserved biodiversity in research museums and at other institutions such as large zoos and aquariums. Support is also needed for the research by which these scientists make

biodiversity known to all of us. Working together we should be able to slow the demise of the many species great and small that still share with us our southeastern waters

Table 6. Rare and vulnerable Trichoptera of the southern Appalachian Mountains.

Family: *Species*	-Species Notes
Brachycentridae:	
Brachycentrus etowahensis Wallace	- reported from 4 medium sized rivers with scattered, sparse riverweed, Podostemum ceratophyllum Michaux in GA and TN.
Glossosomatidae:	
Agapetus jocassee Morse	- reported from only 2 adjacent headwater streams in NC and SC; Category 2 of U.S. Fish and Wildlife Service (1994).
A. vireo Ross	- known from only 2 small streams in TN and 1 in GA; not seen since 1955.
Protoptila cahabensis Harris	"Cahaba saddle-case caddisfly, known only from upper reaches of Cahaba River, AL; Category 2 of U.S. Fish and Wildlife Service (1994).
Helicopsychidae:	
Helicopsyche paralimnella Hamilton	- known only from 2 adjacent, medium sized rivers in NC and SC; Category 2 of U.S. Fish and Wildlife Service (1994).
Hydropsychidae:	
Ceratopsyche etnieri (Schuster & Talak)	"Buffalo Springs caddisfly, known only from a fairly constant temperature springbrook, about 1000 m below its spring source in Grainger County, TN, and from a stream in Smyth County, VA (B. C. Kondratieff, Colorado State University, pers. comm.); Category 2 of U.S. Fish and Wildlife Service (1994).

Cheumatopsyche bibbensis Gordon et al.	- known only from Cahaba River, AL.
C. cahaba Gordon et al.	- known only from headwaters of Cahaba River, AL.
Homoplectra flinti Weaver	- reported previously from only 2 intermittent spring seeps about 30 km apart above 1,200 m in NC, and from a stream in White County, TN; Kondratieff (loc. cit.) has collected adults from seeps in Jackson County, NC.
Oropsyche howellae Ross	- reported previously from only 2 localities in neighboring Jackson and Macon counties, NC; Kondratieff (loc. cit.) has collected adults from Haywood County, NC.
Hydroptilidae:	
Hydroptila anisoforficata Parker & Voshell	- reported from only 2 localities in VA.
H. cheaha Harris	- known from only Dry Creek, a small stream in Talladega County, AL.
H. decia Etnier & Way	"Knoxville hydroptilan micro caddisfly, reported from only 2 small, clear, springfed streams with lush growths of watercress, Nasturtium officianale, in eastern TN; Category 2 of U.S. Fish and Wildlife Service (1994).
H. englishi Hamilton	- known from only 1 medium sized stream at NC/SC border; Category 2 of U.S. Fish and Wildlife Service (1994).
H. lagoi Harris	- known from 2 streams in Tuscaloosa County, AL; especially abundant in Big Sandy Creek just below a large spring; Category 2 of U.S. Fish and Wildlife Service (1994).
H. micropotamis Harris	- restricted to Little River, DeKalb County, northeastern AL.
H. setigera Harris	- known from only 1 specimen from a headwater stream in Calhoun County, AL.

H. talladega Harris	- known from 3 adjacent small and medium sized streams at NC/SC border and 2 small headwater streams in northeastern AL.
Stactobiella cahaba Harris	- known only from Schultz Creek, a tributary of Cahaba River, Bibb County, central AL; Category 2 of U.S. Fish and Wildlife Service (1994).
Lepidostomatidae:	
Lepidostoma etnieri Weaver	- known from 1 specimen found at a stream in Knoxville, TN; Category 2 of U.S. Fish and Wildlife Service (1994).
L. flinti Wallace & Sherberger	- reported from a few high altitude spring locations in NC and SC.
L. glenni Wallace & Sherberger	- reported from only 2 small spring-fed streams in Union County, GA.
L. lobatum Wallace & Sherberger	- reported from 3 small spring-fed streams in Macon County, NC, and Union County, GA.
L. mitchelli Flint & Wiggins	- known from springs at 3 locations in NC above 1,350 m elevation.
Leptoceridae:	
Ceraclea alabamae Harris	- restricted to Little River and its tributaries, De Kalb County, northeastern AL.
Limnephilidae:	
Manophylax altus (Huryn & Wallace)	- larvae and pupae found only on vertical rock faces over which flows a minimal film of water (madicolous or hygropetric habitat) for at least part of the year on Mt. Mitchell (1,800 m elevation), NC, and possibly near Cranberry Glades (823 m elevation), WV.
Philopotamidae:	

Dolophilodes sisko (Ross)	- reported specifically for a small stream in Macon County, NC; 2 other published reports for NC and SC do not provide specific locations.
Wormaldia mohri (Ross)	- known from only a few specimens captured at Smokemont, NC, and Little Pigeon River, Gatlinburg, TN, Great Smoky Mountains National Park, in 1940 and 1944.
W. oconee Morse	- known from only 2 adjacent streams in Oconee County, SC, near NC border; Category 2 of U.S. Fish and Wildlife Service (1994).
Rhyacophilidae:	
Rhyacophila accola Flint	- previously reported from only Smokemont Campground, Great Smoky Mountains National Park, NC; Kondratieff (loc. cit.) has found it outside the Park in a small stream in Haywood County, NC, and by springs in Shining Rock Wilderness Area, NC.
R. amicis Ross	- reported as rare from 3 locations in Henderson, Swain, and Transylvania counties, NC.
R. montana Carpenter	- originally seen at Newfound Gap, TN, and Bryson City, NC, in 1930, recently rediscovered in several other locations by C. R. Parker (National Biological Service, pers. comm.) in small, cold, high elevation seeps with Theliopsyche spp. (Lepidostomatidae).
R. mycta Ross	- reported previously from only 3 locations above 1,300 m in NC; recently seen by Parker (loc. cit) from 2 locations, one in Smoky Mountains and one in the Blue Ridge.
Uenoidae:	
Neophylax auris Vineyard & Wiggins	- reported from 3 locations in Clairborne, Blount, and Anderson counties, TN in springs and small streams.
N. etnieri Vineyard & Wiggins	- found in small, cool streams and spring runs in Clairborne and Knox counties, TN.

N. mitchelli Carpenter	- seen in a few mountain stream locations in NC and SC; recent larval collections by Parker (loc. cit.) suggest that this species may be more common.
N. stolus Ross	- known from only 2 locations along Middle Fork South Branch Potomac River in adjoining counties of VA and WV.
N. toshioi Vineyard & Wiggins	- reported from only Reed Creek, Wythe County, VA, a broad, shallow, warm stream with a bed of rocks and fine sediments; larvae on large rocks.

Table 7. Rare and vulnerable Ephemeroptera of the southeastern Piedmont, Coastal Plain, and Interior Highlands.

Family: *Species*	-Species Notes
Acanthametropodidae:	
Acanthametropus pecatonica (Burks)	- "Pecatonica River mayfly, Coastal Plains province in central and eastern GA and southwestern SC; a fast swimming predator restricted to shifting sand substrates; Category 2 of U.S. Fish and Wildlife Service (1994).
Baetidae:	
Apobaetis etowah (Traver)	- Valley and Ridge province in extreme northwestern GA; unknown as larvae.
Baetis ochris Burks	- Ozark and Ouachita mountains of AR; fairly common in Midwest, but known from only a couple of adults in Southeast; unknown as larvae.
Behningiidae:	
Dolania americana Edmunds & Traver	"American sandburrowing mayfly, rare, localized in Coastal Plain streams with clean, shifting sand; Category 2 of U.S. Fish and Wildlife Service (1994).

Heptageniidae:	
Anepeorus simplex (Walsh)	- Coastal Plains province in central GA; generally from larger sandy rivers at considerable depths where little else is known to live.
Stenonema sinclairi Lewis	- Appalachian Plateaus province in southeast central TN; restricted to very clean, small, soft-water streams with mixed substrate on sandstone bedrock.
Leptophlebiidae:	
Paraleptophlebia georgiana Traver	- Valley and Ridge province in north central GA; larva unknown.
P. jeanae Berner	- East Gulf Coastal Plains province in central AL; larva unknown.
Ephemerellidae:	
Dannella provonshai McCafferty	- Ozark Mountains of western AR; known only from type locality; larvae occur in a clean, medium sized stream in moderate erosional currents among filamentous algal growth.
Serratella frisoni McDunnough	"Frison's serratellan mayfly, limited in Southeast to Interim Low Plateaus province in northwestern AL; somewhat common in Midwest, but its ecology is unknown; Category 2 of U.S. Fish & Wildlife Service (1994).
Tricorythidae:	
Leptohyphes robacki Allen	- Coastal Plains province in eastern GA and southwestern SC from the Savannah River, but no other data are available.
Tricorythodes texanus Traver	- East Gulf Coastal Plains province in southcentral MS; larvae unknown.

Table 8. Rare and vulnerable Odonata of the southeastern Piedmont and Coastal Plain.

Family: *Species*	-Species Notes
Gomphidae:	
Arigomphus maxwelli Ferguson	- known from AL, AR, IL, LA, MS, TN, TX.
Dromogomphus armatus Selys	- known from AL, FL, GA, SC.
Gomphus diminutus Needham	- known from NC, SC.
G. hodgesi Needham	- known from AL, FL, LA, MS.
G. sandrius Tennessen	- "Tennessee clubtail, known from Bedford, Marshall, and Maury counties, TN; Category 2 of U.S. Fish and Wildlife Service (1994).
G. modestus Needham	- known from AL, AR, LA, MS, TX.
Ophiogomphus australis Carle	- known from LA, MS.
O. acuminatus Carle	- known from AL, TN.
O. howei Bromley	- "midget snaketail, known from KY, MA, ME, MN, NC, NY, PA, TN, VA, WI; Category 2 of U.S. Fish and Wildlife Service (1994).
O. westfalli Cooke & Daigle	- "Ozark snaketail, known from AR, MO; Category 2 of U.S. Fish and Wildlife Service (1994).
Progomphus	- "variegated clubtail, known from AL, FL, NC; Category 2 of

bellei Knopf & Tennessen	U.S. Fish and Wildlife Service (1994).
Stylurus notatus Rambur	- not reported from Southeast in past 80 years, but recently recorded in Midwest.
S. potulentus (Needham)	- known from FL, MS.
Cordulegastridae:	
Cordulegaster sayi Selys	- known from FL, GA.
Corduliidae:	
Somatochlora georgiana Walker	- known from AL, FL, MS, NC.
S. ozarkensis Bird	- known from AR.
Libellulidae:	
Libellula jesseana Williamson	- known from FL; a lentic species.
Coenagrionidae:	
Nehalennia pallidula Calvert	- known from southern tip of FL; a lentic species.
Lestidae:	
Lestes spumarius Hagen	- known from southern tip of FL; a lentic species.

Table 9. Rare and vulnerable Plecoptera of the southeastern Piedmont and Coastal Plain.

Family: *Species*	-Species Notes
Capniidae:	
Allocapnia perplexa Ross & Ricker	- known from 5 specimens and 1 locality in Trousdale County, TN.
A. polemistis Ross & Ricker	- known from 4 localities in northwestern AL.
A. tennessa Ross & Yamamoto	- known from 4 localities along the eastern edge of Cumberland Plateau in TN.
Leuctridae:	
Leuctra alabama James	- known from 1 locality in Jackson County, AL.
L. alta James	- known from 2 localities in Calhoun and Tuscaloosa counties, AL.
L. cottaquilla James	- known from 1 locality each in AL, FL, and MS.
L. crossi James	- known from 1 locality in Calhoun County, AL.
L. szczytkoi Stark & Stewart	- known from 1 locality in LA.
Taeniopterygidae:	

Taeniopteryx robinae Kondratieff & Kirchner	- known from 1 stream in Barnwell County, SC.
Chloroperlidae:	
Alloperla furcula Surdick	- known from 3 localities in South AL and the Savannah River Site, SC.
A. natchez Surdick & Stark	- known from several sites in southwestern MS.
Perlidae:	
Beloneuria jamesae Stark & Szczytko	- known from 2 sites near Cheaha Mountain, AL.
Neoperla harrisi Stark & Lentz	- known from 3 localities in northwestern AL.
Perlesta lagoi Stark	- known from 4 locations in MS.
Perlodidae:	
Hydroperla phormidia Ray & Stark	- known from 3 streams in northwestern FL and from Savannah River of GA/SC.

Table 10. Rare and vulnerable Trichoptera of the southeastern Piedmont and Coastal Plain.

Family: *Species*	-Species Notes

Dipseudopsidae:	
Phylocentropus harrisi Schuster & Hamilton	- recorded from only 2 small Coastal Plain streams in Southern Pine Hills of AL.
Glossosomatidae:	
Agapetus alabamensis Harris	- known from only 2 small intermittent streams of Cumberland Plateau in AL.
A. diacanthus Edwards	- reported once from Cumberland Plateau of TN, its specific habitat is unknown.
A. spinosus Etnier & Way	- known from only 5 locations on Cumberland Plateau in AL and TN from both large and small streams.
Protoptila georgiana Denning	- reported from AL, GA, and VA; this rarely encountered Piedmont species is known from large, fast-flowing streams.
Lepidostomatidae:	
Lepidostoma compressum Etnier & Way	- known from only 3 specimens taken at University of Tennessee Cumberland Plateau Research and Education Center.
L. weaveri Harris	- reported from 2 small, spring-fed, intermittent streams at southern edge of Cumberland Plateau in AL.
Theliopsyche tallapoosa Harris	- only 3 specimens collected once beside a swift, rocky bottomed Piedmont stream 6 m wide in AL; Category 2 of U.S. Fish and Wildlife Service (1994).
Hydropsychidae:	
Cheumatopsyche kinlockensis Gordon et al.	- known only from type locality, a small stream on Cumberland Plateau in Bankhead National Forest, AL.

C. richardsoni Gordon	- known only from Upper Three Runs Creek, Savannah River Site, downstream of southern Aiken, SC; presently one of the most common species in this vulnerable stream.
Hydropsyche alabama Lago & Harris	- only known from Cowarts Creek, a small, sand bottomed stream of Coastal Plain southern AL.
H. catawba Ross	- rarely collected species of Piedmont region from Savannah River basin to VA in small to medium-sized streams.
H. patera Schuster & Etnier	- known only from type locality, Harpath River in Nashville Basin, central TN.
H. rotosa Ross	- rare in AL, TN, and VA in upland streams.
Hydroptilidae:	
Hydroptila coweetensis Huryn	- reported from 3 small tributaries in higher elevations of AL and NC.
H. fuscina Harris	- restricted in distribution to 3 known streams of Cumberland Plateau and Highland Rim in AL.
H. metteei Harris	- known from 2 small streams in Coastal Plain of southern AL.
H. scheiringi Harris	- reported from 3 steams in Southern Pine Hills region of Coastal Plain in southern AL.
H. wetumpka Harris	- known only from a small, rocky Piedmont stream in AL.
Neotrichia sepulga Harris	- known only from a small tributary of Sepulga River in Coastal Plain of AL.
Ochrotrichia elongiralla Harris	- recorded only from type locality, a small, gravel bottomed stream in upper Cumberland Plateau in AL; Category 2 of U.S. Fish and Wildlife Service (1994).

O. weoka Harris	- reported only from type locality, a small, rocky Piedmont stream in AL.
Polycentropodidae:	
Polycentropus carlsoni Morse	"Carlson's Polycentropus caddisfly, Category 2 of U.S. Fish and Wildlife Service (1994); known from only 2 nearby first order stream localities in Upper Piedmont of SC and from 2 nearby first order streams in the Upper Piedmont of AL.
P. rickeri Yamamoto	- known from 3 records from small upland streams in AL, TN, and VA.
Rhyacophilidae:	
Rhyacophila alabama Harris	- single known population occurs in a small, intermittent tributary in Paint Rock River system of northern AL.
R. carolae Harris	- known from only 2 specimens collected from a tributary of Bee Branch in Bankhead National Forest of AL.
Sericostomatidae:	
Agarodes alabamensis Harris	- known from only 2 specimens collected at type locality, a small, sandy-bottomed stream in Lime Hills of AL Coastal Plain; Category 2 of U.S. Fish and Wildlife Service (1994).
Uenoidae:	
Neophylax securis Vineyard & Wiggins	- reported from 3 widely separated, small, headwater streams on Cumberland Plateau of AL and TN.

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