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Southern Appalachian streams at risk: implications for mayflies, stoneflies, caddisflies, and other aquatic biota

JOHN C. MORSE
Clemson University, Department of Entomology, Long Hall, Box 340365, Clemson, SC 29634-0365, USA
BILL P. STARK
Mississippi College, Department of Biology, P.O. Box 4186, Clinton, MS 39058, USA
and
W. PATRICK McCAFFERTY
Purdue University, Department of Entomology, Entomology Hall, West Lafayette, IN 47907, USA

ABSTRACT

1. The Ephemeroptera, Plecoptera and Trichoptera (EPT; mayfly, stonefly and caddisfly, respectively) faunas of the southern Appalachian Mountains are rich in species, including many endemic species. The species richness is a result of unique geological, climatological, and hydrological features of the region.

2. Humans have impacted, and are impacting, the stream faunas in several significant ways, primarily through air pollution (with acid precipitation), introduction of exotic forest pests, impoundments (ponds and reservoirs), sedimentation (from road building, development, deforestation, farming), toxic substances (industrial effluent, agricultural and golf course insecticides), and organic enrichment (agricultural and golf course fertilizers, trout farm effluent).

3. Nineteen species of Ephemeroptera, 17 species of Plecoptera and 38 species of Trichoptera are identified as examples that are probably rare and vulnerable to extirpation in the southern Appalachian Mountains.

4. The task of saving the streams and their biotas from further degradation will require thoughtful public discourse and thorough baseline and long-term research efforts.

INTRODUCTION

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 colonial descendants. Especially in recent years, the spectacular vistas have attracted tourists and development for vacationers and retirees. On the other hand, the rugged terrain and dense vegetation historically have discouraged travel, large-scale agriculture and heavy industrialization. The purpose of this overview is to consider (1) the structural features that account for the unique aquatic insect fauna of the southern Appalachians, (2) the historical changes that humans and other forces have made in the streams and rivers of the region, (3) the impacts of those changes on the aquatic insect fauna (especially on the Ephemeroptera, Plecoptera, and Trichoptera), and (4) speculations on future changes and impacts.

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STRUCTURAL FEATURES

For purposes of this discussion, the southern Appalachians are defined as that region covered by the Blue Ridge and Ridge and Valley Physiographic Provinces from Maryland and West Virginia southward into Georgia and Alabama. The Appalachian Mountains are bordered on the north west by the Allegheny and Cumberland Plateau Region. They are bordered on the south east by the wide Piedmont Region, from which the mountains are separated by the Blue Ridge Escarpment, sometimes dropping 300 m or more on an average 45° angle. Streams crossing the Escarpment often produce spectacular waterfalls. Elevations in the Blue Ridge Region generally range between 600–1000 m; those in the Ridge and Valley Region are generally between 300–900 m (Isphording and Fitzpatrick, 1992).

Streams of the southern Appalachians are unique for several reasons. (1) These mountains were never glaciated. Therefore, the saprolitic ultisol and inceptisol soils are generally residual and not sedimentary; that is, they weathered chemically *in situ*. Soils at the lower elevations frequently are deep and highly structured vertically, with a conspicuous sandy or loamy (A) horizon above a loamy or clayey (Bt) 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 these mountains were not glaciated also means that many species, including aquatic insects, evolved in place; others moved south with the glaciers and were left as isolated, speciating populations when the ice receded (Ross and Ricker, 1971).

(2) These mountains have relatively mild winters and summers. This warmer climate means that there is greater biological activity than 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 south-eastern 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 left isolated populations that facilitated higher rates of species diversification.

(3) Shade from this vegetation is seasonal, limiting headwater stream autochthonous primary production from April to 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 $m^{-2} yr^{-1}$ in the southern Appalachians (Bray and Gorham, 1964).

(4) Precipitation is relatively high, averaging 100–200 cm yr^{-1} (40–80 in/yr; Wallace *et al.*, 1992). Consequently, most streams are permanent, with small seeps and springs occurring frequently. Since 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.

(5) The streams of the region 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.

(6) The streams also have high physico-chemical variability, especially in mid-order reaches (3rd to 5th order streams). This 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).

These factors and probably others, taken together, have resulted in some of the highest aquatic insect species diversity and one of the highest concentrations of endemic species on the continent (Holt *et al.*, 1969).

Table 1. Number of species (%) of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) in the mountains and other physiographic regions of North and South Carolina (Brigham *et al.*, 1982).

	Mountains only	Mountains and other	Total in mountains	Other only
Ephemeroptera	54 (31%)	70 (41%)	124 (72%)	49 (28%)
Plecoptera	42 (36%)	63 (53%)	105 (89%)	13 (11%)
Trichoptera	104 (38%)	96 (35%)	200 (73%)	74 (27%)
Total	200 (35%)	229 (41%)	429 (76%)	136 (24%)

For example, 72%, 89% and 73% of the species of mayflies, stoneflies and caddisflies, respectively, in the two Carolinas occur in the Mountains (Table 1), with 31%, 36% and 38% of them occurring there exclusively (Brigham *et al.*, 1982). Among all 1653 caddisfly species known in North America (including Greenland and Mexico—Morse, 1993), 104 (6%) are endemic to the Eastern Highlands, defined as the Cumberland Plateau, Appalachian Plateaus, Appalachian Mountains, and Piedmont (Hamilton and Morse, 1990) and 63 species (4%) are endemic to the southern Appalachian Mountains.

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. The beaver were essentially eliminated from the southern Appalachians by the late 1700s (Hackney and Adams, 1992). Early European settlers practised slash and burn agriculture and travelled 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 nagivable streams.

The United States Army Corps of Engineers, the Tennessee Valley Authority, and electrical power companies have built many reservoirs in the Southeast, especially during the past 50 years. Most southeastern reservoirs have been built in the upland regions, including many in the 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 slowly 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 US Forest Service began providing protection from fire and heavy cutting. Initially, they favoured selection management, maintaining uneven-aged forests, but this was difficult to accomplish 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.

Changes brought about by these activities, especially the heavy cutting adjacent to the stream 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, in press). 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, personal communication).

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 weaken and kill trees and other vegetation in the stream riparian zones (C. R. Parker, personal communication), reducing allochthonous nutrient inputs.

Agriculture in the region is often the primary non-point source of sedimentation, pesticides and nutrients. Sediments apparently cause most of the damage 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. Developments are generally in 'the nicest places', i.e. beside streams, and are generally associated with golf courses kept 'pretty' with pesticides and fertilizers. New housing in the southern Appalachian Mountains of Georgia, North Carolina, South Carolina and Tennessee declined somewhat in recent years, probably because of downturns in the economy, from a high of 9500 in 1984 to a low of 5600 in 1990; economic improvements are likely to see this factor increase, with concomitant declines in stream water quality.

Sedimentation problems associated with forestry operations are diminishing in the southern Appalachians. Contrary to the practices in the Pacific Northwest, clearcuts average only about 10 ha in Appalachian National Forests. 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 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% of the forestry-associated sediment in streams), has significantly reduced the sediment input in National Forest lands. Much of the forest land is in private ownership, however; private landowners in South Carolina, for example, are accepting the South Carolina Forestry Commission's 'Best Management Practices', but more slowly (85% compliance in South Carolina in 1992; D. H. Van Lear, Clemson University, and T. O. Adams, SC Forestry Commission, personal communication).

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

IMPACTS ON MAYFLIES, 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 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 Banks (stoneflies and caddisflies, mostly during 1905–1914) and Traver (mayflies during 1932–1937), extensive studies of the aquatic insects of the region were undertaken by staff of the Illinois Natural History in the 1930s, examining the region's mayflies (B. D. Burks), stoneflies (T. H. Frison) and caddisflies (H. H. Ross). However, faunistic and ecological knowledge was gathered in such a sporadic manner in those early years that few general statements can be made about changes in the stream biota.

Nineteen species of mayflies, 17 species of stoneflies and 38 species of caddisflies are probably rare and vulnerable to extirpation (Tables 2–4). Because of taxonomic problems and the fact that some habitats, such as small streams and seeps, have been poorly explored, the species included 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 (1991) cited one of these mayfly species and six of these caddisfly species in their 'Category 2', for which further information is needed in order to justify listing as endangered or threatened. Whether these particular 74 species have always been rare or whether there were at one time other species that were then rare and are now extinct cannot be determined. Some of these species have not been collected since the 1930s and 1940s and may now be extirpated, such as the caddisfly *Agapetus vireo* Ross and the stoneflies *Acroneuria arida* (Hagen) and *Amphinemura mockfordi* (Ricker).

Table 2. Rare and vulnerable Ephemeroptera of the Southern Appalachian Mountains.

Species	Habitat
Baetidae	
Barbaetis benfieldi Kennedy	Medium to large streams with pea-gravel and clean water
Callibaetis pretiosus Banks	Rare in scattered southern localities, including mountain stream pools
Heterocloeon petersi (Müller-Liebenau)	Only known from few well-oxygenated southern Appalachian streams
Procloeon quaesitum (McDunnough)	Mountain streams with pea-gravel substrate
Procloeon rivulare (Traver)	Requires very high water quality
Ephemerellidae	
Drunella longicornis Traver	Widespread, clean-water, riffle species
Drunella waya Traver	Somewhat rare species on sand-gravel substrates with moderate current
Ephemerella berneri Allen and Edmunds	Rare south-eastern species with little known of its ecological requirements
Ephemerella floripara McCafferty	Rare species in headwater streams between 200 and 800 m elevation, with mixture of stones and sand or bedrock and sand substrate and with moderate to somewhat stronger currents
Serratella carolina Berner and Allen	Rare, south-eastern, riffle species
Serratella spiculosa Berner and Allen	Rare, south-eastern, riffle species; US Fish & Wildlife Service Category 2, not reported since 1963
Ephemeridae	
Litobrancha recurvata (Morgan)	A mainly north-eastern species, somewhat rare in the Southeast, requiring small, clean, cold-water streams with silt/marl substrate
Heptageniidae	
Iron subpallidus 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
Rhithrogena amica Traver	
Rhithrogena exelis Traver	
Rhithrogena fuscifrons Traver	
Rhithrogena rubicunda Traver	
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 3. Rare and vulnerable Plecoptera of the Southern Appalachian Mountains.

Species	Habitat
Capniidae	
Allocapnia brooski Ross	Known from two streams in Hawkins and Sevier Counties, Tennessee
Allocapnia fumosa Ross	Known from five streams at high elevations in Haywood County, North Carolina, Sevier County, Tennessee, and near Mt Rogers, Virginia
Leuctridae	
Megaleuctra williamsae Hanson	Known from scattered localities around Great Smoky Mountains National Park in Tennessee, and one locality each in North Carolina, South Carolina, and Virginia
Nemouridae	
Amphinemura mockfordi (Ricker)	Known from two localities at Monteagle, Tennessee; last seen in 1938
Zapada chila (Ricker)	Known from only a short stretch of one stream near Newfound Gap, Tennessee
Taeniopterygidae	
Strophopteryx inaya Ricker & Ross	Known from two localities, one each in Jackson and McDowell Counties, North Carolina
Taeniopteryx nelsoni Kondratieff & Kirchner	Known only from the Mount Rogers area of Virginia
Chloroperlidae	
Sweltsa urticae (Ricker)	Known from one locality in Great Smoky Mountains National Park and reported from Virginia without specific locality
Peltoperlidae	
Tallaperla elisa Stark	Known from one locality in Great Smoky Mountains National Park
Perlidae	
Acroneuria petersi Stark & Gaufin	Known from one locality in Georgia and one in Great Smoky Mountains National Park, Tennessee
Acroneuria arida (Hagen)	Reported from Georgia, North Carolina, New Jersey, Pennsylvania, and Tennessee, but there are no recent Georgia, North Carolina, or Tennessee records; most records are from the 1930s
Beloneuria georgiana (Banks)	Fairly common in a restricted area of North Carolina and Georgia, but at low densities; probably a top carnivore in small spring seepage areas
Beloneuria stewarti Stark & Szczytko	Fairly common in low elevation seeps of Georgia, North Carolina, South Carolina, and Tennessee, but at low densities
Perlodidae	
Diploperla morgani Kondratieff & Voshell	Known from several localities in south-western Virginia and adjacent areas of West Virginia
Isoperla bellona Banks	Known from Black Mountain, North Carolina, and from Georgia; no recent sightings
Isoperla distincta Nelson	Known from two localities in Tennessee and one in North Carolina
Oconoperla innubila (Needham & Claassen)	Known from eight scattered spring seepage areas in North Carolina, South Carolina, and Tennessee

Many of these rare species are known from only one or a few locations with pea-size gravel or in springbrooks and seepage areas. Those requiring pea-gravel are susceptible to sedimentation problems. For example, one of us (BPS) has observed the disappearance of *Malirekus hastatus* (Banks), *Yugus bulbosus* (Frison), and *Remenus bilobatus* (Needham and Claassen) on 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 *Pseudogoera singularis* Carpenter and *Heterocloeon* species have been observed (by JCM) to disappear as a result of clearcutting to the stream banks. Another riffle species, *Serratella spiculosa* Berner and Allen, is listed by the United States Fish and Wildlife Service (1991) 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 (1991) Category 2. The stoneflies *Beloneuria georgiana* (Banks), *Megaleuctra williamsae* Hanson and *Oconoperla innubila* (Needham and Claassen) are also vulnerable spring-inhabiting species. *Zapada chila* (Ricker) may also be threatened by acid precipitation because of its habitat at such high elevations in the Appalachians.

THE FUTURE

What are the prospects for slowing or stopping the loss of southern Appalachian stream faunas? Federal forestry practices in the southern Appalachians seem to be improving, although the trend toward uneven-aged management, with its higher road density and more frequent re-entries into the forest may be more harmful to freshwater ecosystems than the even-aged management used until recently. Controls on point source industrial effluent are slowly taking hold. Construction of major dams and other large water projects has slowed and the rate of coal mining in the region has dropped.

The principal problems for the future seem to be air pollution, forest pest outbreaks, farmers and private timber harvesters relaxing their guard against soil erosion and runoff of pesticides and nutrients, organic pollution from trout farms, and the press of humanity for developing homes, highways, and recreational opportunities in this scenic region, with resultant sedimentation (C. R. Parker, National Park Service, and D. R. Lenat, North Carolina Division of Environmental Management, personal communication). The cumulative effects of air pollution and associated acid precipitation are 'the single greatest concern' in the Great Smoky Mountains National Park. Major outbreaks of forest pests—especially by exotic species such as the balsam woolly adelgid and the gypsy moth—are second (C. R. Parker, personal communication) with resultant detriment to aquatic resources expected from canopy loss and introduction of pesticides attempting to control them.

Our task remains to provide better public justification for maintaining biodiversity, and setting aside wilderness areas (which include entire catchments) or enhancing environmental quality in already degraded regions while addressing concerns for banned logging, loss of local tax revenues, exclusion of motorized vehicles, 'invasion' by 'outsiders', and perceived threats to private ownership and rights. With public support it will be possible to enact legislation where technical knowledge exists and to enforce existing legislation (Wallace *et al.*, 1992). The Wild and Scenic Rivers Act, which originally included the Chattooga (GA, NC, SC), Obed (TN), and New (NC) Rivers, has provided some protection for important biodiversity resources. Other streams have been identified in the Nationwide Rivers Inventory (National Parks Service, 1981, 1982) and should be considered seriously for inclusion in the Wild and Scenic River System. Additional streams can be, and are being, protected by stream classification systems in place in the various states.

The most important research need is for baseline and long-term trend investigations. Published and unpublished baseline data from earlier investigations by Etnier, Wallace, Voshell, Tarter, and Morse and their students (since the 1970s) should be compiled. Only a few facilities, such as the US Forest Service's Research Station at Coweeta, North Carolina, are providing long-term research in the region that will permit comparison of historical conditions against present and future circumstances. Similar long-term study facilities should be established elsewhere in the southern Appalachians to provide a sound basis on which wise

Table 4. Rare and vulnerable Trichoptera of the Southern Appalachian Mountains.

Species	Habitat
Brachycentridae	
Brachycentrus etowahensis Wallace	Reported from four medium sized rivers with scattered, sparse *Podostemum ceratophyllum* Michaux (riverweed) in Georgia and Tennessee
Glossosomatidae	
Agapetus jocassee Morse	Known from only two adjacent headwater streams in North Carolina and South Carolina; US Fish & Wildlife Service Category 2
Agapetus vireo Ross	Known from only two small streams in Tennessee and one in Georgia; not seen since 1955
Protoptila cahabensis Harris	Known only from the upper reaches of the Cahaba River, Alabama
Helicopsychidae	
Helicopsyche paralimnella Hamilton	Known only from two adjacent, medium sized rivers in North Carolina and South Carolina, US Fish & Wildlife Service Category 2
Hydropsychidae	
Ceratopsyche etnieri (Schuster & Talak)	Known only from Buffalo Springs, Grainger County, Tennessee, a fairly constant-temperature springbrook, about 1000 m below spring source; US Fish & Wildlife Service Category 2
Cheumatopsyche bibbensis Gordon, Harris, & Lago	Known only from the Cahaba River, Alabama
Cheumatopsyche cahaba Gordon, Harris, & Lago	Known only from the headwaters of the Cahaba River, Alabama
Homoplectra flinti Weaver	Known from only two intermittent spring seeps about 30 km apart in North Carolina
Oropsyche howellae Ross	Reported from only two localities in neighbouring counties of North Carolina
Hydroptilidae	
Hydroptila anisoforficata Parker & Voshell	Reported from only two localities in Virginia
Hydroptila cheaha Harris	Known from only one small stream (Dry Creek) in Talladega County, Alabama
Hydroptila decia Etnier & Way	Reported from only two small, clear, spring-fed streams with lush growths of watercress (*Nasturtium officianale* R. Brown); US Fish & Wildlife Service Category 2
Hydroptila englishi Hamilton	Known from only one medium sized stream at North/South Carolina state line; US Fish & Wildlife Service Category 2
Hydroptila lagoi Harris	Known from two streams in Tuscaloosa County, Alabama; especially abundant in Big Sandy Creek just below a large spring
Hydroptila micropotamis Harris	Restricted to the Little River, De Kalb County, in north-eastern Alabama
Hydroptila setigera Harris	Known only from a single specimen from a headwater stream in Calhoun County, Alabama
Hydroptila talladega Harris	Known from three adjacent small and medium sized streams at the North/South Carolina border and two small headwater streams in north-eastern Alabama
Stactobiella cahaba Harris	Known only from Schultz Creek, a tributary of the Cahaba River, Bibb County, central Alabama
Lepidostomatidae	
Lepidostoma etnieri Weaver	Known from a single specimen at a stream in Knoxville, Tennessee
Lepidostoma flinti Wallace & Sherberger	Reported from a few high altitude spring locations in North and South Carolina

(*continued*)

Table 4. (*continued*)

Lepidostomatidae (*continued*)	
Lepidostoma glenni Wallace & Sherberger	Reported from only two small spring-fed streams in Union County, Georgia
Lepidostoma lobatum Wallace & Sherberger	Reported from three small spring-fed streams in Macon County, North Carolina, and Union County, Georgia
Lepidostoma mitchelli Flint & Wiggins	Known from springs at three locations in North Carolina above 1350 m elevation
Leptoceridae	
Ceraclea alabamae Harris	Restricted to the Little River and its tributaries, De Kalb County, north-eastern Alabama
Limnephilidae	
Madeophylax 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 (1800 m), North Carolina, and possibly near Cranberry Glades (823 m), West Virginia
Philopotamidae	
Dolophilodes sisko (Ross)	Reported specifically for a small stream in Macon County, North Carolina; two other published reports for North Carolina and South Carolina do not provide specific locations
Wormaldia mohri (Ross)	Known only from few specimens captured at Smokemont, North Carolina, and Little Pigeon River, Gatlinburg, Tennessee, Great Smoky Mountains National Park, in 1940 and 1944
Wormaldia oconee Morse	Known from only two adjacent streams in Oconee County, South Carolina, near the North Carolina border; US Fish & Wildlife Service Category 2
Rhyacophilidae	
Rhyacophila accola Flint	Reported only from Smokemont Campground, Great Smoky Mountains National Park, North Carolina
Rhyacophila amicis Ross	Reported as rare from three locations in Henderson, Swain, and Transylvania Counties, North Carolina
Rhyacophila montana Carpenter	Originally seen at Newfound Gap, Tennessee, and Bryson City, North Carolina, in 1930, recently rediscovered in several other locations by C. R. Parker (personal communication) in small, cold, high-elevation seeps with *Theliopsyche* spp. (Lepidostomatidae)
Rhyacophila mycta Ross	Reported previously only from three locations above 1300 m in North Carolina; recently seen by C. R. Parker (personal communication) 'from two locations, one in the Smokies and one in the Blue Ridge'
Uenoidae	
Neophylax auris Vineyard & Wiggins	Reported from three locations in Clairborne, Blount, and Anderson Counties, Tennessee, in springs and small streams
Neophylax etnieri Vineyard & Wiggins	Found in small, cool streams and spring runs in Clairborne and Knox Counties, Tennessee
Neophylax mitchelli Carpenter	Seen in a few mountain stream locations in North Carolina and South Carolina; recent larval collections by C. R. Parker suggest that this species may be more common
Neophylax stolus Ross	Known only from two locations along the Middle Fork South Branch Potomac River in adjoining counties of Virginia and West Virginia
Neophylax toshioi Vineyard & Wiggins	Reported only from Reed Creek, Wythe County, Virginia; a broad, shallow, warm stream with a bed of rocks and fine sediments; larvae on large rocks

management decisions may be made. According to C. R. Parker (personal communication), the National Park Service has begun to implement a nationwide Inventory and Monitoring Program to address the issue of long-term data needs. The Great Smoky Mountains National Park (GSMNP) was chosen as one of the prototype monitoring parks (of 10 proposed to be designated); studies of aquatic resources are a large part of the GSMNP programme.

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