PSOCOPTERAN SPECIES ASSOCIATED WITH EASTERN HEMLOCK IN THE SOUTHERN APPALACHIANS

Carla Coots[1,2], Paris Lambdin[1], Jerome Grant[1], Rusty Rhea[3], and Edward Mockford[4]
[1]Department of Entomology and Plant Pathology, The University of Tennessee, Knoxville, TN 37996

[2]Corresponding author, E-mail: cdillin1@utk.edu

[3]USDA Forest Service, Forest Health Protection, 200 Weaver Boulevard, Asheville, NC 28804.

[4]School of Biological Sciences, Illinois State University, Normal, IL 61790-4120.

Eastern hemlock, *Tsuga canadensis* (L.) Carrière, comprises a vital component of biological diversity (Jordan & Sharp 1967; Lapin 1994; Tingley et al. 2002; Buck 2004; Buck et al. 2005; Dilling et al. 2007; Dilling et al. 2009) and economical (Travel Industry Association 2006; Woodsen 2001) and environmental stability (Evans 2002; Snyder et al. 2004) within its geographical range. Hemlock woolly adelgid, *Adelges tsugae* Annand (Hemiptera: Adelgidae), is an exotic insect species capable of rapidly reducing populations of eastern hemlock throughout the eastern United States (McClure & Fergione 1977; Buck et al. 2005; Ellison et al. 2005). As such, documenting the biodiversity of insects associated with this host tree is imperative. More than 400 insect species have been recorded to be associated with eastern hemlock in the southern Appalachians (Wallace & Hain 2000; Buck et al. 2005; Lynch et al. 2006; Dilling et al. 2007; Dilling et al. 2009).

Psocopterans comprise a major component of arthropod diversity on eastern hemlock, occupying an important ecological role as major consumers of microepiphytes as well as an integral food source for predators (Thornton 1985; Mockford 1993). Population densities of psocopterans can be extremely high. For example, densities of Psocoptera on the bark of larch, i.e., *Larix decidua* Mill., have been reported at > 4,000/m^2, which Thornton (1985) equates to > 6,000/m^2 of land surface. In this study, we document the psocopteran richness within the canopy of eastern hemlock in the southern Appalachians.

Eastern hemlocks (n = 6) were selected on 5 Nov 2005 at Indian Boundary within the Cherokee National Forest located in Monroe County in southeast Tennessee (35°23.787 N, 84°06.662 W). All trees (14-18 m in height) were located in a shortleaf pine–oak (type 76) forest (Eyre 1980). Because of the diversity of habitat preferences in trees and mobility among species of Psocoptera, 3 sampling methods were selected to capture a wide range of psocopteran species and were executed monthly from Nov 2005 through Sep 2008. Also, a platform lift was used to sample the bottom, middle and top stratum on each tree in Aug 2006, Sep 2007, and Jun 2008. Specimens were collected using direct sampling (beat sheet, handpicking, and trunk vacuuming) with collected specimens placed into labeled (date, site and tree location, sampling type) alcohol-filled vials and taken to the laboratory for identification. Beat-sheet samples (4 per tree) were taken at each direction by striking each branch 5 times with a one-meter rod, while visual observations were conducted on each tree for 5 min per stratum, and direct trunk vacuuming occurred on 61 cm of the circumference of the tree's trunk.

During this study, 3,740 adult and nymph psocopteran specimens were collected and identified, representing 44 species, 23 genera, and 11 families (Table 1). These species represent 14.3% of the species (307) and 41% of the families of Psocoptera documented in North America (Mockford 1993; Lienhard & Smithers 2002). In addition, 29 species represent new records for Tennessee and 33 species represent new county records for the state. The number of psocopteran species on eastern hemlock comprises almost 10% of the known insect species associated with this host tree.

The greatest number of species was recorded for Psocidae followed by Lachesillidae and Peripsocidae. Species within these 3 families represent 37%, 23%, and 11%, respectively, of the total species identified on eastern hemlock. The families Dasydemellidae, Lepidopsocidae, Mesopsocidae, Myopsocidae, and Stenopsocidae were each represented by only 1 species. However, the least number of specimens for a species was collected for *Lachesilla andra* Sommerman (n = 16) (Lachesillidae) followed by *L. anna* Sommerman (n = 22), *Peripsocus stagnivagus* Chapman (n = 27) (Peripsocidae), and *Lachesilla corona* Chapman (n = 29) (Lachesillidae). The greatest number of specimens was collected for *Cerastipsocus venosus* (Burmeister) (n = 246) (Psocidae) followed by *Valenzuela flavidus* (Stevens) (n = 201) (Caeciliusidae). Species identified from eastern hemlock constitute the highest number of psocopteran species recorded from a single tree species.

The dominant distribution pattern of the species identified is the eastern deciduous forest pattern as defined and described by Mockford (1993) (i.e., corresponding with delimited east-

TABLE 1. SPECIES OF PSOCOPTERA ASSOCIATED WITH EASTERN HEMLOCK IN THE SOUTHERN APPALACHIANS AND CORRESPONDING COLLECTION METHODS, DISTRIBUTION, AND HABITATS.

Family	Genus	Species	Author	Collecting Method*	No. Specimens	Distribution**	Tennessee New Record	Habitat***
Caeciliusidae	*Valenzuela*	*flavidus*	(Stevens)	B, H, T	201	COS	No	Broad-leaf trees, rarely conifers (1), hemlock (2)
Caeciliusidae	*Valenzuela*	*pinicola*	(Banks)	B, H	123	NA	Yes	Foliage of pines and juniper, noted on spruce and Douglas fir (1)
Caeciliusidae	*Xanthocaecilius*	*quillayute*	(Chapman)	B, H	110	NA	No	Evergreen trees and shrubs, live oak, American holy, and wax myrtle (1)
Caeciliusidae	*Xanthocaecilius*	*sommermanae*	(Mockford)	B, H	59	EUS & WUS	No	Broad-leaf plants (1), hemlock (2)
Dasydemellidae	*Teliapsocus*	*conterminus*	(Walsh)	B, T	87	NA	No	Foliage of broad-leaf and conifer trees, ground litter (1)
Ectopsocidae	*Ectopsocopsis*	*cryptomeriae*	(Enderlein)	B, H	67	COS	No	Hanging dead leaves (1)
Ectopsocidae	*Ectopsocus*	*meridio nalis*	Ribaga	B, H	35	COS	Yes	Dead leaves (1)
Lachesillidae	*Anomopsocus*	*amabilis*	(Walsh)	B, H, T	66	NA	Yes	Hanging dead leaves, occasionally foliage of conifers (1)
Lachesillidae	*Lachesilla*	*andra*	Sommerman	B	6	NA	Yes	Dead standing grass stems and leaves (1)
Lachesillidae	*Lachesilla*	*anna*	Sommerman	B, T	22	NA	Yes	Dead leaves and shrubs and trees (1)
Lachesillidae	*Lachesilla*	*contraforcepeta*	Chapman	B, H	55	NA	Yes	Foliage of pines, junipers, and conifers (1)
Lacheillidae	*Lachesilla*	*corona*	Chapman	B	29	NA	Yes	Dead leaves on a variety of woody and herbaceous plants (1)
Lachesillidae	*Lachesilla*	*forcepeta*	Chapman	B, H,T	36	NA	Yes	Foliage of junipers and occasionally pine (1)
Lacheillidae	*Lachesilla*	*major*	Chapman	B, T	48	EUS	Yes	Dead leaves of broad-leaf plants and occasionally conifers (1)
Lachesillidae	*Lachesilla*	*nubilis*	(Aaron)	B, T	74	NA	Yes	Dead vegetation and grasses (1)
Lachesillidae	*Lachesilla*	*pedicularia*	(L.)	B,T,H	67	NA	Yes	Conifers, dead grasses, drying grain crops (1)
Lachesillidae	*Lachesilla*	*rufa*	(Walsh)	B, H	46	EUS	Yes	Dead leaves (1)
Lepidopsocidae	*Echmepteryx*	*hageni*	(Packard)	T	76	NA	Yes	Bark of tree trunks and branches, stone outcrops (1)
Mespsocidae	*Mesopsocus*	*unipunctatus*	(Müller)	B,H,T	122	NA	No	Variety of broad-leaf and needle leaf trees
Myopsocidae	*Lichenomima*	*lugens*	(Hagen)	H, T	94	NA	No	Shaded tree trunks, outcrops, and stone and cement structures (1)
Peripsocidae	*Peripsocus*	*alboguttatus*	(Dalman)	H, T	38	COS	No	Hemlock, spruce, larch, and other conifers (1)
Peripsocidae	*Peripsocus*	*maculosus*	Mockford	H, T	49	NA	No	Foliage and branches of conifers, larch, pine, juniper, spruce, also oak and sumac (1), hemlock (2)

*B, Beatsheet; H, Handpick; and T, Trunk Vacuum
**NA, North America; COS, Cosmopolitan; EUS, Eastern United States; WUS, Western United States; and CUS, Central United States
***Habitats recorded by (1) Mockford (1993) and (2) Dilling et al. (2009)

TABLE 1. (CONTINUED) SPECIES OF PSOCOPTERA ASSOCIATED WITH EASTERN HEMLOCK IN THE SOUTHERN APPALACHIANS AND CORRESPONDING COLLECTION METHODS, DISTRIBUTION, AND HABITATS.

Family	Genus	Species	Author	Collecting Method*	No. Specimens	Distribution**	Tennessee New Record	Habitat***
Peripsocidae	*Peripsocus*	*madidus*	(Hagen)	H, T	55	NA	Yes	Hemlock, juniper, spruce, pine, and broad-leaf trees (1)
Peripsocidae	*Peripsocus*	*stagnivagus*	Chapman	B, T	27	EUS	Yes	Trunks and branches of trees, of spanish moss , and occasionally stone outcrops (1)
Peripsocidae	*Peripsocus*	*subfasciatus*	(Rambur)	H, T	37	NA	No	Needle-like and broad-leaf trees (1), hemlock (2)
Philotarsidae	*Aaroniella*	*badonneli*	(Danks)	H, T	148	EUS	No	Trees and shrubs, stone outcrops (1), hemlock (2)
Philotarsidae	*Aaroniella*	*maculosa*	(Aaron)	B, H, T	113	EUS	No	Bottomland forest trees (1), hemlock(2)
Psocidae	*Blaste*	*opposita*	(Banks)	B, H, T	154	NA	No	Branches of broad-leaf and conifer trees (1), hemlock (2)
Psocidae	*Blaste*	*quieta*	(Hagen)	H, T	147	NA	Yes	Branches o f broad-leaf and conifer trees (1)
Psocidae	*Blastopsocus*	*lithinus*	(Chapman)	B, H, T	5	NA	Yes	Trunks and branches of broad-leaf and conifer trees (1)
Psocidae	*Cerastipsocus*	*venosus*	(Burmeister)	B, H, T	246	NA	Yes	Trunks and branches of broad-leaf and conifer trees (1)
Psocidae	*Hyalopsocus*	*floridanus*	(Banks)	B, H, T	165	NA	Yes	Trunks and branches of broad-leaf trees and pines (1)
Psocidae	*Indiopsocus*	*infumatus*	(Banks)	B, H	114	EUS & CUS	Yes	Dead branches o f broad-leaf tress (1)
Psocidae	*Loensia*	*moesta*	(Hagen)	B, H, T	63	EUS	Yes	Trunks and branches of broad-leaf trees and conifers (1)
Psocidae	*Metylophorus*	*novaescotiae*	(Walker)	H, T	186	NA	No	Branches of broad-leaf trees, shrubs, and conifers (1), hemlock (2)
Psocidae	*Metylophorus*	*purus*	(Walsh)	B, T	78	NA	Yes	Trunks and branches of broad-leaf trees and conifers (1)
Psocidae	*Psocus*	*leidyi*	Aaron	B, H, T	59	EUS	Yes	Trunks and branches of broad-leaf trees and pines, occasionally stone outcrops (1)
Psocidae	*Ptycta*	*polluta*	(Walsh)	B, H, T	62	EUS	No	Branches of broad-leaf and conifer trees and shrubs (1)
Psocidae	*Trichadenotecnum*	*alexanderae*	Sommerman	B, H, T	41	CUS	Yes	Bark o f trees and shaded stone outcrops (1)
Psocidae	*Trichadenotecnum*	*castum*	Betz	B, T	57	COS	Yes	Trunks and branches of broad-leaf and conifer trees (1)
Psocidae	*Trichadenotecnum*	*merum*	Betz	B,T	169	EUS & CUS	Yes	Trunks and branches of broad-leaf and conifer trees (1)
Psocidae	*Trichadenotecnum*	*quaesitum*	(Chapman)	B, H, T	66	NA	Yes	Branches of broad-leaf trees, hemlocks, and bald cypress (1)
Psocidae	*Trichadenotecnum*	*slossonae*	(Banks)	B, H, T	139	NA	Yes	Branches of broad-leaf and conifer trees (1)
Stenopsocidae	*Graphopsocus*	*cruciatus*	(L.)	B, H, T	43	EUS & WUS	Yes	Unknown

*B, Beatsheet; H, Handpick; and T, Trunk Vacuum
**NA, North America; COS, Cosmopolitan; EUS, Eastern United States; WUS, Western United States; and CUS, Central United States
***Habitats recorded by (1) Mockford (1993) and (2) Dilling et al. (2009)

ern deciduous forest (Braun 1972) in the eastern United States). This eastern deciduous forest pattern is noted as having poorly documented northern delineation due to limited collecting in this area, but generally is found from central New Brunswick to central Ontario and southward to peninsular Florida. *Lachesilla pedicularia* (L.) and *Teliapsocus conterminus* (Walsh) were noted as having other distribution patterns (Mockford 1993). In the eastern United States, *T. conterminus* (Walsh) generally follows the eastern deciduous forest pattern but has a southern limit that extends farther into Florida (Mockford 1993). *Lachesilla pedicularia* is noted as having a large outdoor range, and as such does not fit into a specific distribution pattern. Distribution of male *Ptycta polluta* (Walsh) was documented to be the southern Appalachians in Tennessee (Mockford 1993) with bisexual populations of *P. polluta* and *Peripsocus subfasciatus* (Rambur) appearing to be restricted to hemlock stands. *Graphopsocus cruciatus* (L.) has been classified as an introduced species (Mockford 1993), and has a varied distribution, including Tennessee, in the eastern and western United States, where it has been documented most often from areas around coastal waterways and inlets. The majority of the species identified are noted as having a variety of habitat preferences and broad distribution range (Table 1).

Summary

Psocopterans collected (3,740) represented 44 species, 23 genera, and 11 families. Most species of Psocoptera found in association with eastern hemlock in the southern Appalachians exist on a variety of vegetative hosts, and as such their population numbers should be minimally impacted by any decline in eastern hemlock populations. However, loss of eastern hemlock populations could be detrimental to a few species (i.e., *P. polluta* and *P. subfasciatus*) that are dependent upon this host for survival. Of those species identified, 29 represent new records for Tennessee and 33 species represent new county records for the state.

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