The Status and Distribution of *Tsuga canadensis* (L.) Carr. (eastern hemlock) on the Delmarva Peninsula, and the Presence of the Hemlock Woolly Adelgid (*Adelges tsugae* Annand)

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ABSTRACT.—Disjunct and isolated populations of *Tsuga canadensis* (eastern hemlock) are thought to represent relict stands of a once widespread forest that was present during the late Pleistocene. As the post-glacial climate warmed, these forests retreated to the north and to higher elevations in the south, creating a discontinuous distribution with peripheral populations restricted to areas with favorable conditions. The Delmarva Peninsula of the Atlantic Coastal Plain physiographic province is one region where disjunct populations of eastern hemlock survive. This study has documented 22 extant populations associated with tidal rivers and streams in 6 counties on Delmarva. The hemlock woolly adelgid (*Adelges tsugae*), an introduced insect pest native to Japan and China, has severely impacted native populations of eastern hemlock from Massachusetts to North Carolina. Hemlock woolly adelgid has been confirmed present in all but one of the native populations of eastern hemlock on Delmarva and threatens the health of these stands. Eastern hemlock on the inner Coastal Plain of the Delmarva Peninsula is an uncommon occurrence and this paper documents the current status and distribution of the species and describes overall habitat conditions. The authors hope to encourage conservation activities for these native populations and to stimulate ecological studies in order to learn more about their disjunct occurrence on Delmarva. In addition, this paper also reports on the presence of hemlock woolly adelgid in native populations of eastern hemlock on Delmarva and hopes to motivate control efforts.

INTRODUCTION

Tsuga canadensis (L.) Carr. (eastern hemlock) is endemic to eastern North America (Flora of North America 1993) and prefers cool, humid climates (Godman and Lancaster 1990). Eastern hemlock reaches its northeast extreme in New Brunswick and Nova Scotia, Canada, and is found throughout New England, New York, northern New Jersey, Pennsylvania, and eastern Ohio (Godman and Lancaster 1990). It reaches its northwest extreme in Minnesota and Wisconsin (Godman and Lancaster 1990). Within the northern portions of its range, it grows up to an elevation of 730 m above sea-level (Godman and Lancaster 1990). In the south, the species occurs through the Appalachian Mountains into northern Georgia and northeastern Alabama where it reaches its southern geographical limit (Godman and Lancaster 1990). Though eastern hemlock occurs at lower elevations in the southern Appalachians, the most frequent occurrences in this region are at elevations of 610 to 1520 m above sea-level (Godman and Lancaster 1990).

Disjunct populations of eastern hemlock occur in southeast Minnesota (Godman and Lancaster 1990), southwest Wisconsin (McIntosh 1950; Eickmeir et al. 1975; Parshall 2002), extreme southern Michigan and western Ohio (Godman and Lancaster 1990), southern Indiana (Daubenmire 1931; Friesner and Potzger 1931; Hotchkiss et al. 1976), western Kentucky (Godman and Lancaster 1990), northwest Alabama (Segars et al. 1951; Harper 1952), Virginia (Nemeth 1973; Harvill et al. 1992), North Carolina (Holmes 1883; Oosting and Hess 1956; Hardin and Cooper 1967), and northern Georgia (Bormann and Platt 1958).

Disjunct populations of eastern hemlock have attracted attention and research through the years (Friesner and Potzger 1931; Oosting and Hess 1956; Bormann and Platt 1958; Hardin and Cooper 1967; Nemeth 1973; Eickmeir et al. 1975; Kavanagh and Kellman 1986; Parshall 2002), and the general conclusion is that these isolated populations of eastern hemlock represent stands from a once widespread forest present during the late Pleistocene Epoch (600,000 to 12,000 years BP). Palynologic studies on the Delmarva Peninsula (Sirkin et al. 1977; Denny et al. 1979; Groot and Jordan 1999; Andres and Howard 1999) have identified *Tsuga* pollen from the late Tertiary period (Pliocene Epoch, 5.3 to 1.8 million years BP) to early Quaternary (Pleistocene Epoch, 1.8 million to 8,000 years BP). Many studies (Friesner and Potzger 1931; Oosting and Hess 1956; Bormann and Platt 1958; Hardin and Cooper 1967; Nemeth 1973; Eickmeir et al. 1975; Kavanagh and Kellman 1986; Parshall 2002) suggest that as the post-glacial climate warmed (perhaps 20,000 to 15,000 years BP), eastern hemlock retreated to the north and to higher elevations in the southern Appalachians. This retreat created a dissected and discontinuous distribution with peripheral populations being restricted to areas of favorable microclimate and edaphic conditions. The Delmarva Peninsula is one region where disjunct populations of eastern hemlock survive. Based on this study, 22 native populations of eastern hemlock are currently known extant on the Delmarva (Table 1; Figure 2).

Currently, eastern hemlock is known extant on the Coastal Plain of Long Island, New York (Greg Edinger, pers. comm.), south-central New Jersey (David Snyder, pers. comm.), the Delmarva Peninsula (Kent Co., Maryland: 18 May 2003, *McAvoy 5800* with Sophia and Ross Elliott, Claude E. Phillips Herbarium, Delaware State University, Dover, Delaware), the Western Shore of Maryland (Dill 1962; Doug Samson, pers. comm.; Calvert Co., Maryland: 27 September, 2001, *McAvoy 5311*, Claude E. Phillips Herbarium, Delaware State University, Dover, Delaware), and southeast Virginia (Harvill et al. 1992; Gary Fleming, pers. comm.). There are historical collections of eastern hemlock from southeast Pennsylvania that may have been from Pennsylvania's Coastal Plain province, but the species is thought to no longer occur at these locations (Ann Rhoads, pers. comm.).

The presence of eastern hemlock on the Delmarva Peninsula has been documented in the literature, but only as entries in checklists (Shreve et al. 1910; Tatnall 1946), or a flora (Brown and Brown 1972) and usually with only brief annotation. The first literature report of eastern hemlock on the Delmarva Peninsula was by Shreve et al. (1910) who reported "a single locality in the Coastal Zone (Caroline County, Watts Creek)." Tidestrom (1913) cited Shreve's report, but also made note of a new

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Table 1. Distribution and population data of eastern hemlock on the Delmarva Peninsula. The presence of HWA was found in all populations, except Number 1.

Population Number	County, State	Associated River and/or Creek	Approximate Number of Trees	Trunk Diameters (in, smallest to largest)	Seedlings and Saplings
1	New Castle, Delaware	Appoquinimink River/Drawyers Creek	1	5	
2	New Castle	Appoquinimink River/Drawyers Creek	15 to 25	5 to 10	✓
3	Cecil, Maryland	Little Bohemia Creek	75 to 100	15 to 20	
4	Cecil	Sassafras River/Cox Creek	50 to 75	5 to 25	✓
5	Cecil	Sassafras River/Back Creek	50 to 75	10 to 20	✓
6	Kent, Maryland	Sassafras River/Fox Hole Landing	50 to 75	10 to 38	✓
7	Kent	Sassafras River/Jacobs Creek	75 to 100	10 to 29	✓
8	Kent	Sassafras River/Wilson Point	50 to 75	5 to 25	✓
9	Kent	Sassafras River/Swantown Creek	100 to 125	5 to 25	✓
10	Kent	Sassafras River/Turner Creek	150 to 200	10 to 25	✓
11	Kent	Sassafras River/Lloyd Creek	50 to 75	10 to 15	✓
12	Kent	Still Pond Creek	50 to 75	10 to 17	✓
13	Queen Anne's, Maryland	Wye East River	75 to 100	5 to 20	✓
14	Queen Anne's	Wye East River	5 to 10	5 to 10	
15	Talbot, Maryland	Wye East River	50 to 75	15 to 20	✓
16	Talbot	Wye East River/Pickering Creek	50 to 75	15 to 28	✓

Table 1. Continued

Population Number	County, State	Associated River and/or Creek	Approximate Number of Trees	Trunk Diameters (in, smallest to largest)	Seedlings and Saplings
17	Talbot	Tuckahoe Creek	75 to 100	5 to 15	✓
18	Caroline, Maryland	Tuckahoe Creek	30 to 40	15 to 22	
19	Caroline	Tuckahoe Creek	15 to 25	15 to 22	✓
20	Caroline	Tuckahoe Creek	25 to 50	5 to 10	✓
21	Caroline	Choptank River/Watts Creek	200 to 300	10 to 28	✓
22	Caroline	Choptank River/Mill Creek	40 to 50	5 to 10	✓

population on Tuckahoe Creek in Talbot and Caroline Counties, Maryland, which he described as "lining both banks of the river." Eastern hemlock on Delmarva was also recognized by Tatnall (1946), who pointed out, "there are eastern hemlock groves of considerable extent [in Caroline and Talbot Counties, Maryland], these appear to be native stands, probably remnants of an ancient forest." The collection record (Appendix 1) also documents its occurrence on the Peninsula, but these records have not been compiled and reviewed.

Threatening the health of eastern hemlock populations on the Delmarva Peninsula is the introduction into North America of the hemlock woolly adelgid (HWA), *Adelges tsugae* Annand (Homoptera: Adelgidae). HWA is an introduced insect pest destructive to native and ornamental hemlock trees in the eastern United States. Native to Japan and China (McClure et al. 2001), HWA was first reported in eastern North America in the 1950's at Maymont Park in Richmond, Virginia (Souto et al. 1996). The original owner of Maymont Park, James Dooley collected plants from around the world during the late 1800's until his death in 1922. Although it has not been documented, Dooley may have collected HWA infested hemlocks from Asia. From the time of its first report in North America, HWA spread slowly and was only considered an occasional pest on ornamental hemlocks. However, when HWA reached the range of native eastern hemlock populations in the mid-1980's, the rate of spread increased dramatically (Souto at al. 1996). By 1993 HWA was established from Virginia to Massachusetts. Its range currently extends from Massachusetts in the north, to eastern West Virginia in the west, and to northwestern South Carolina in the south (U.S.D.A. Forest Service; http://www.fs.fed.us/na/morgantown/fhp/hwa/hwa11201.jpg). Some of the first observations of infestations on ornamental hemlock on Delmarva were in the early 1990's (Bob Rabaglia, forest entomologist, Maryland Dept. of Ag., and Mike Valenti, Delaware Dept. of Ag., pers. comm.). The USDA Forest Service (2002) documented the presence of HWA on Delmarva from the Maryland counties of Queen Anne's (1991), Cecil (1992), Caroline (2002), Kent (2002), and Talbot (2002), and from New Castle County, Delaware (1993).

The intent of this paper is to report on the current status and distribution of eastern hemlock on the Delmarva Peninsula, describe overall habitat conditions, encourage conservation of these uncommon populations, and stimulate ecological studies in order to learn more about their disjunct occurrence on Delmarva. In addition, this paper also reports on the presence of HWA in native populations of eastern hemlock on Delmarva and hopes to motivate control efforts.

The Study Area

The Delmarva Peninsula (Figure 1) is an area lying entirely within the Atlantic Coastal Plain physiographic province of the eastern United States. The Peninsula lies south of the fall line (a term applied to the boundary between the Appalachian Piedmont province and the Atlantic Coastal Plain) of New Castle Co., Delaware and Cecil Co., Maryland, and is bordered on the east by the Delaware River, Delaware Bay and the Atlantic Ocean, and on the west by the Elk River and Chesapeake Bay. It includes the Coastal Plain province of Delaware (three counties), the Eastern Shore of Maryland (nine counties), and the Eastern Shore of Virginia (two counties). The

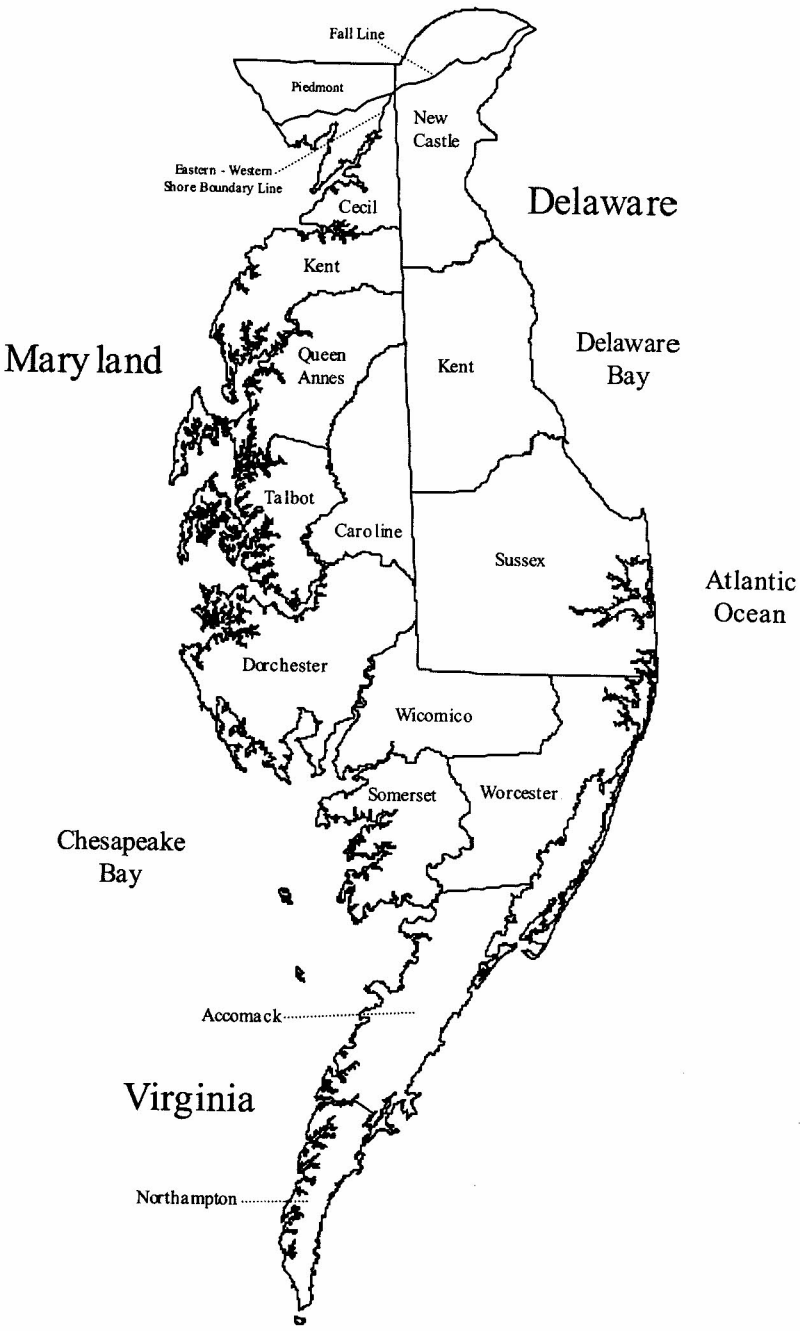

Figure 1. The Delmarva Peninsula with State and County boundaries indicated.

climate of the Peninsula is moderated by the Delaware Bay, Chesapeake Bay, and the Atlantic Ocean and is characterized by cool winters and warm humid summers. The mean annual temperature is 13.0°C. The coldest month of the year is January, with an average temperature of 1.5°C. The warmest month is July with an average temperature of 24° C. The average annual precipitation is 111.9 cm. March, July, and August have the highest average amounts of rainfall: 10.6 cm, 10.1 cm, and 13.2 cm, respectively. Climate data is based on a recording station in Sussex Co., Delaware near the town of Georgetown (about central Delmarva; Research and Education Center, Georgetown Delaware, College of Agriculture and Natural Resources, University of Delaware; http://www.rec.udel.edu/TopLevel/Weather.htm).

Methods

Data reported here are based primarily on field surveys done by the first author from 1995 to 2003. Data are also based on herbaria searches (Towson State University, Towson, Maryland; Delaware State University, Dover, Delaware; University of Maryland, College Park, Maryland; Philadelphia Academy of Natural Sciences, Philadelphia, Pennsylvania) and review of the literature. Historical (20 years or greater) locations obtained from specimens and the literature were searched for in order to document their current status. Newly discovered populations were the result of field surveys conducted within potential habitat and from conversations with knowledgeable individuals. Potential habitat was determined through review of U.S.G.S. topographical maps (1: 24,000) to identify the appropriate landscape signature (north and east facing slopes above tidal creeks and rivers). When an historical population of eastern hemlock was relocated, or a new population discovered, the following data were collected: estimated number of individuals of eastern hemlock; the smallest and largest trunk diameter's at breast height (DBH, measured in inches); the presence/absence of eastern hemlock seedlings and saplings; aspect; and plant species composition. In addition, the following general observations were noted: position of eastern hemlock individuals on the slope (base of slope, mid-slope, crest of slope); spacing of eastern hemlock individuals (wide or close); position within the canopy (lower canopy, upper canopy) of the larger individuals of eastern hemlock; crown condition of the larger individuals of eastern hemlock (densely or sparsely foliated); the presence/absence of dead standing trunks of eastern hemlock; the degree of herbaceous plant cover in the herb-layer (low, moderate, dense); and soil drainage (dry, mesic). Criteria for defining a seedling, sapling, and tree follow Sharpe et al. (1986): seedling = individual up to 0.9 m in height; sapling = individual less than 10 cm DBH, and 0.9 to 3 m in height; tree = 10 cm or greater DBH, and 3 m or greater in height. No attempts were made to accurately measure tree heights or to age individuals through coring. The amount of area covered by a population of eastern hemlock was determined by marking its approximate location on a U.S.G.S. topographical map, then calculating the linear extent from the map. The elevations of slopes supporting eastern hemlock populations were also determined using U.S.G.S topographical maps by examining contour intervals. Soil mapping units and percent slope were determined through review of U.S.D.A. Soil Conservation Service county soil surveys (Caroline Co., MD, 1964; Cecil Co., MD, 1973; Kent Co., MD, 1982; Queen Anne's Co., MD,

1966; Talbot Co., MD, 1970; New Castle Co., DE, 1970). Voucher specimens were made from each population to document their locations, and have been deposited at the Claude E. Phillips Herbarium, Delaware State University, Dover, Delaware. Scientific and common names for all plant species listed follows McAvoy and Bennett (2001).

To document the presence/absence of HWA in each population studied, random samples (low hanging branches with foliage) were taken from about 10 individuals in a population. However, one population contained no more than 10 individuals, in this case, about five samples were taken. Another population contained only one individual, in this case, one sample was taken. No attempt was made to determine the degree of severity (low, moderate, heavy) of HWA infestations. Samples were examined for presence/absence of HWA at the Department of Entomology at Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Results

Distribution of eastern hemlock on the Delmarva Peninsula

This report documents 22 distinct, native populations of eastern hemlock on the Delmarva Peninsula (Table 1, Figure 2). A population was defined as containing at least one individual, and is separated from another population by at least 0.5 km (0.3 mi), or a natural break in the landscape, e.g., streams, creeks, coves, and rivers. Eastern hemlock on Delmarva is distributed primarily in the northwest and west-central portions of the Peninsula. The northern most populations are in Cecil Co., Maryland (Little Bohemia Creek) and New Castle Co., Delaware (Appoquinimink River/ Drawyers Creek). The southern most populations are in Caroline Co., Maryland (Choptank River/Watts Creek and Mill Creek). The largest number of populations (Table 1) was found on the Sassafras River (8 in Cecil and Kent Co.'s, MD), Tuckahoe Creek (4 in Talbot and Caroline Co.'s, MD), and the Wye East River (4 in Queen Anne's and Talbot Co.'s, MD).

Habitat and Population Description

With few exceptions, populations of eastern hemlock on the Delmarva Peninsula were all nearly identical in physiognomy. Therefore, a habitat description that represents eastern hemlock populations on Delmarva as a whole is provided.

All populations of Eastern hemlock on Delmarva occur on slopes ranging from 6 to 12 m in height (Table 2) above tidal rivers and creeks. The average overall height of slopes supporting eastern hemlock populations on Delmarva was 8 m. Based on U.S.D.A. county soil surveys, the percent slope varied from 0 to 5%, 2 to 5%, 5 to 10%, 15 to 30%, 25 to 30%, and 15 to 40% (Table 2). The majority of populations occurred on north-facing slopes (16 populations), four populations occurred on east-facing slopes, and two populations occurred on west-facing slopes (Table 2). Individuals of eastern hemlock were usually found growing near the base of slopes to just above mid-slope. Occasionally, individuals were found growing on the crest of slopes and beyond into upland flats. Because eastern hemlock populations on Delmarva occurred on narrow linear slopes, it was difficult to determine the amount of actual land area in hectares covered by these populations. However, the largest

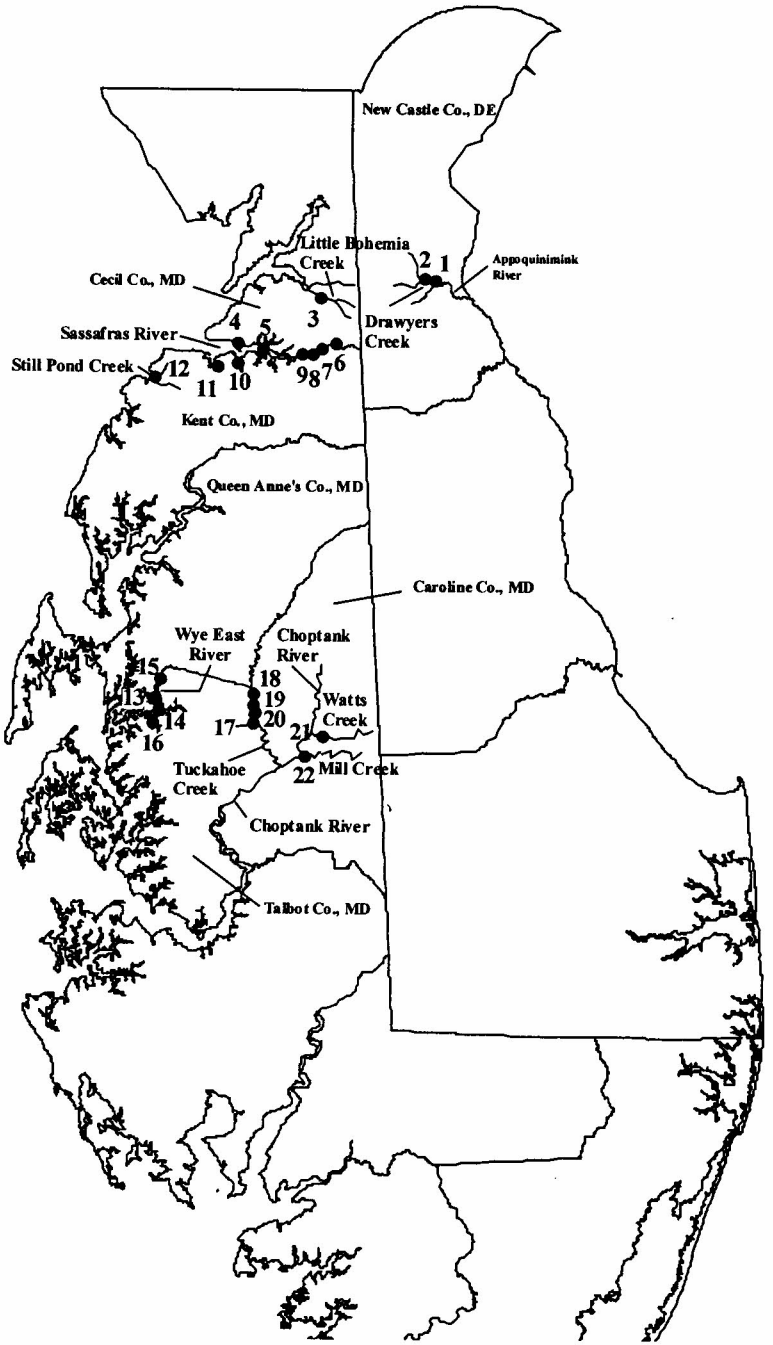

Figure 2. The geographic distribution of eastern hemlock along rivers and creeks on the Delmarva Peninsula. Numbers refer to a distinct population described in Table 1.

populations (e.g., Choptank River/Watts Creek, Caroline Co., MD; Sassafras River/Turner Creek, Kent Co., MD; Sassafras River/Swantown Creek, Kent Co., MD) did not cover more than 1 km of linear slope.

Plant species composition of eastern hemlock populations on Delmarva were fairly consistent. The canopy was usually dominated by *Quercus prinus* (chestnut oak), with *Fagus grandifolia* (American beech) as a frequent associate. Occasionally, *Acer rubrum* (red maple), *Carya alba* (mockernut hickory, synonym = *C. tomentosa*), *Ilex opaca* (American holly), *Liriodendron tulipifera* (tulip poplar), *Nyssa sylvatica* (black gum), *Quercus alba* (white oak), and *Q. velutina* (black oak) were also found in the canopy. The shrub layer was usually thin to absent, with *Kalmia latifolia* (mountain laurel) and *Vaccinium pallidum* (low-bush blueberry) being the most frequently encountered species. Species diversity in the herbaceous layer was usually low, with *Deschampsia flexuosa* (crinkled hairgrass) usually dominating. *Polypodium virginianum* (rock polypody) was a frequent associate and was often found in widespread, colonial patches. Other associates occasionally found in the herbaceous layer included: *Carex pensylvanica* (a sedge) *C. swannii* (a sedge), *C. tonsa* (a sedge), *Epigaea repens* (trailing arbutus), and *Mitchella repens* (partridge berry). The degree of plant cover in the herbaceous layer was low for all populations sampled.

Eastern hemlock on the Delmarva Peninsula never forms pure stands. The number of individuals in a population varied (Table 1), from only one (Appoquinimink River/Drawyers Creek, New Castle Co., DE) to as many as 300 (e.g., Choptank River/Watts Creek, Caroline Co., MD). Eight populations contained 50 to 75 individuals, and four contained 75 to 100. Only three populations contained more than 100. Eastern hemlock usually appears as moderately to widely spaced individuals, although occasionally, individuals can be closely spaced. Individual eastern hemlocks were usually found within the lower canopy. In nine populations, the smallest trunk diameter measured of a tree-size individual was 5 in (12.7 cm) DBH (Table 1). The average trunk diameter of the smallest trees measured in all populations was 9 in (23 cm) DBH. The largest trunk diameters measured were: 38 in (97 cm) DBH, one individual at the Sassafras River/Fox Hole Landing population (Kent Co., MD); 29 in (74 cm) DBH, one individual at the Sassafras River/Jacobs Creek population (Kent Co., MD); 28 in (71 cm) DBH, two individuals at the Wye East River/Pickering Creek (Talbot Co., MD) population, and two individuals at the Choptank River/Watts Creek (Caroline Co., MD) population (Table 1). At 12 of the 22 populations sampled, no tree greater than 20 in (51 cm) DBH was measured (Table 1). The average trunk diameter of the largest trees measured in all populations was 20 in (51 cm) DBH. In 18 populations sampled, seedling and sapling-size specimens were observed, usually in areas with low plant density and moderate sun. In all eastern hemlock populations sampled, many of the larger [(15-20 in 38-51 cm DBH)] tree-size individuals observed had very small crowns with a low number of branches. In addition, all populations (with the exception of the population containing one individual) contained at least one dead standing trunk.

Based solely on personal observations by the first author, soils of eastern hemlock slopes appeared to be mesic, but well drained. Based on species composition of the plant community (*Quercus prinus, Fagus grandifolia, Vaccinium pallidum,*

Table 2. Physical features of eastern hemlock populations on the Delmarva Peninsula: aspect, elevation, percent slope, and soil mapping unit.

Population Number	County, State	Associated River and/or Creek	Aspect	Elevation of Slope (meters)	% Slope	Soil Mapping Unit
1	New Castle, Delaware	Appoquinimink River/Drawyers Creek	N	12	15 to 30	Sassafras and Matapeake
2	New Castle	Appoquinimink River/Drawyers Creek	N	6	15 to 30	Sassafras and Matapeake
3	Cecil, Maryland	Little Bohemia Creek	N	9	15 to 40	Sassafras and Aura
4	Cecil	Sassafras River/Cox Creek	E	6	15 to 40	Sassafras and Aura
5	Cecil	Sassafras River/Back Creek	N	12	15 to 40	Sassafras and Aura
6	Kent, Maryland	Sassafras River/Fox Hole Landing	N	9	15 to 40	Sassafras and Colts Neck
7	Kent	Sassafras River/Jacobs Creek	E	12	15 to 40	Sassafras and Colts Neck
8	Kent	Sassafras River/Wilson Point	N	9	15 to 40	Sassafras and Colts Neck
9	Kent	Sassafras River/Swantown Creek	E	12	15 to 40	Sassafras and Colts Neck
10	Kent	Sassafras River/Turner Creek	N	12	15 to 40	Sassafras and Colts Neck
11	Kent	Sassafras River/Lloyd Creek	N	9	15 to 40	Sassafras and Colts Neck
12	Kent	Still Pond Creek	N	6	10 to 15	Sassafras gravelly loam
13	Queen Anne's, Maryland	Wye East River	N	6	15 to 30	Downer
14	Queen Anne's	Wye East River	N	6	2 to 5	Ingelside sandy loam

Table 2. Continued

Population Number	County, State	Associated River and/or Creek	Aspect	Elevation of Slope (meters)	% Slope	Soil Mapping Unit
15	Talbot, Maryland	Wye East River	N	6	0 to 5	Galestown loamy sand
16	Talbot	Wye East River/Pickering Creek	N	6	5 to 10	Matapeake loam
17	Talbot	Tuckahoe Creek	E	6	·	Steep Land
18	Caroline, Maryland	Tuckahoe Creek	W	6	25 to 30	Galestown loamy sand
19	Caroline	Tuckahoe Creek	W	6	25 to 30	Galestown loamy sand
20	Caroline	Tuckahoe Creek	N	6	25 to 30	Galestown loamy sand
21	Caroline	Choptank River/Watts Creek	N	6	25 to 30	Galestown loamy sand
22	Caroline	Choptank River/Mill Creek	N	6	25 to 30	Galestown loamy sand

Kalmia latifolia), and personal experience of the first author, soils of eastern hemlock slopes likely have a low pH.

HWA was confirmed present in all eastern hemlock populations sampled during this study, with the exception of one (Appoquinimink River/Drawyers Creek, New Castle Co., DE). The intensity or severity of these infestations were not measured.

Discussion

Studies of other disjunct populations of eastern hemlock (Daubenmire 1931; Friesner and Potzger 1931; Oosting and Hess 1956; Borman and Platt 1958; Nemeth 1973; Hotchkiss et al. 1976; Gary Fleming, pers. comm.) in the eastern U.S. describe habitat conditions similar, or identical to what was found in eastern hemlock populations on the Delmarva Peninsula. These studies reported disjunct populations of eastern hemlock occurring on north-facing and east-facing slopes above creeks or rivers that usually covered a small land area. These studies also reported that many individuals within populations have small trunk diameters, and support sparse shrub and herb layers. Also in common with Delmarva eastern hemlock populations, these studies note that *Quercus prinus* was conspicuous in the overstory with *Fagus grandifolia* occasionally appearing, and *Kalmia latifolia* was often present in the understory. In the southern Appalachian mountains, eastern hemlock is usually restricted to north-facing and east-facing slopes, coves, or cool moist valleys (Oosting and Hess 1956; Godman and Lancaster 1990). This study of eastern hemlock populations on Delmarva, as well as others (Daubenmire 1931; Friesner and Potzger 1931; Oosting and Hess 1956; Borman and Platt 1958; Nemeth 1973; Hotchkiss et al. 1976; Gary Fleming, pers. comm.), show that disjunct populations of eastern hemlock occupy similar topographic and climatic sites.

Review of U.S.D.A. Soil Conservation Service county soil surveys (Caroline Co., MD, 1964; Cecil Co., MD, 1973; Kent Co., MD, 1982; Queen Anne's Co., MD, 1966; Talbot Co., MD, 1970; New Castle Co., DE, 1970), found that descriptions of soil mapping units were not consistent between county surveys. For example, where populations of eastern hemlock were found, soil texture, soil drainage, and soil pH were not always included in the overall characterization of the mapping units. Despite inconsistencies between county soil surveys, eastern hemlock slopes on Delmarva appear to share similar soil characteristics described by Godman and Lancaster (1990). Godman and Lancaster (1990) stated that soils supporting eastern hemlock were universally characterized as moist to very moist, but with good drainage and are typically highly acid. According to the U.S.D.A. county soil surveys for Delmarva, soil drainage, when described varied. For example, terms such as "droughty," "well-drained," and "excessively drained" were used. Based on personal observations by the first author, soils of eastern hemlock slopes overall appeared to be moist, but well drained. Further review of the U.S.D.A. county soil surveys where populations of eastern hemlock occur, found that soil texture, when described also varied for mapping units. For example, sandy loam, loamy sand, gravelly loam, and silt loam were all used to characterize soil texture. Soils in Kent Co., Maryland where eastern hemlock populations have been found, are described as being "strongly acid to extremely acid" (U.S.D.A Soil Conservation Service, Kent Co., MD, 1982). The presence of acid-

loving plants, such as *Quercus prinus, Fagus grandifolia, Vaccinium pallidum,* and *Kalmia latifolia* found growing within eastern hemlock populations on Delmarva, indicate that soils overall likely have a low pH.

The association of eastern hemlock populations on Delmarva with rivers and creeks help to explain in part why these disjunct stands have persisted on the Peninsula. Studies by Segars et al. (1951) and Oosting and Hess (1956), suggested that the occurrence and persistence of disjunct populations of eastern hemlock may be partially attributed to the relatively high humidity of the habitats. Oosting and Hess (1956) point out that most populations were in close proximity to a permanent stream with local humidity probably higher than that of the surrounding area. As mentioned above, individuals of eastern hemlock were usually found near the base of the slope, to just above mid-slope, but occasionally on the crest of slopes and beyond. Oosting and Hess (1956) found on the "bluffs" where eastern hemlock occurred exclusively, that temperature and evaporation were lower and available soil moisture greater than on the crest of the bluff where eastern hemlock was absent. In addition, Oosting and Hess (1956) suggested that an excess of evaporation over precipitation may limit the range of eastern hemlock southward. Perhaps this is one factor why eastern hemlock is currently known only from the northern Atlantic Coastal Plain (Long Island, New York to southeast Virginia) and not further south.

Native populations of eastern hemlock on the Delmarva Peninsula are uncommon. Data presented in this paper, as well as the literature and the early collection record (Appendix 1) supports this status. Shreve et al. (1910) reported that eastern hemlock is known from "a single locality in the Coastal Zone (Caroline County, Watts Creek)." Tidestrom (1913) pointed out that "so far as I know we have only one published record of this tree from the coastal plain," which is in reference to Shreve's report, but in the same paper discusses a new population he visited in 1912. Fowler (1957) states that "hemlock is rare or absent from the coastal plain in Maryland." Brown and Brown (1972) described eastern hemlock in Maryland as "mostly in the Mountain Zone, a few small stands occurred on the Eastern Shore and one along Hellen Creek in Calvert County [Western Shore]." The collection record (Appendix 1) revealed only seven historical localities of eastern hemlock on Delmarva. All seven sites were relocated by the first author, and 15 sites were newly discovered and vouchered. Although eastern hemlock certainly appears to be an uncommon species on Delmarva at this time, it is likely that additional populations will be discovered in the future. A review of U.S.G.S. topographical maps indicates more potential habitat that needs to be explored.

It should be noted that Tatnall (1946) thought the occurrence of eastern hemlock on Drawyers Creek (Appoquinimink River, New Castle Co., DE) "may have sprung from planted trees in the grounds of near-by Drawyers Church." This population is nearly identical to the native populations in the Maryland counties of Delmarva. A new population was also discovered during this study on Drawyers Creek that is 0.8 km (0.5 mi) to the east. In addition, Drawyers Church was constructed in 1861 and it is likely impossible to determine if the eastern hemlock found on the grounds of the church were ever actually planted. Therefore, the first author believes the Appoquinimink River/Drawyers Creek (New Castle Co., DE) populations are native.

The Sassafras River appears to be the strong-hold for eastern hemlock on the Delmarva Peninsula. The largest number (8) of populations of eastern hemlock found during this study were on the Sassafras River in Cecil and Kent Co., Maryland (Table 1, Figure 2). Though discontinuous, these populations extended from the west on Lloyd Creek, to the east at Fox Hole Landing for a distance of about 18 km (12 mi). Three populations (Turner Creek, Swantown Creek, and Jacobs Creek) supported 100 or more individuals, and five populations supported up to 75 individuals. It is estimated that the Sassafras River supports at least 800 individuals of eastern hemlock, more than any other river system sampled during this study. In addition, the largest diameter trees measured were from Sassafras River populations [38 in DBH (98 cm) Fox Hole Landing, 29 in DBH (73 cm) Jacobs Creek]. The average diameter of the largest trees from all populations sampled on the Sassafras River is 25 in (62 cm) DBH, which is greater than the overall average of 20 in (50 cm) DBH from all populations sampled during this study. Additionally, all populations on the Sassafras River contained seedlings and saplings.

With the exception of a few populations (e.g., Choptank River/Watts Creek, Caroline Co., MD; Sassafras River/Turner Creek, Kent Co., MD; Sassafras River/ Swantown Creek, Kent Co., MD), the overall vigor of eastern hemlock on Delmarva appears to be poor, perhaps due to their disjunct, peripheral occurrence. Central populations of a species distribution experience the most favorable environmental conditions, and these favorable conditions decrease with an increase in distance from the center (Kavanagh and Kellman 1986; Lesica and Allendorf 1995). As a result, populations disjunct from the center of the species range are likely to occur in ecologically marginal or stressful conditions, and are typically less vigorous than central populations (Kavanagh and Kellman 1986; Lesica and Allendorf 1995). Although the following characteristics do not necessarily indicate a low degree of vigor, all populations covered less than one linear kilometer (0.6 mi) of slope; only 3 populations had more than 100 estimated individuals, and 8 had no more than 75; most crowns were narrow with a low number of branches supporting foliage; and all but one population had at least one dead standing trunk. Early studies (Holmes 1883; Daubenmire 1931; Friesner and Potzger 1931; Oosting and Hess 1956; Nemeth 1973; Gary Fleming, pers. comm.) of disjunct populations of eastern hemlock also describe conditions of stress and low vigor. For example, descriptions such as: "do not present a healthy vigorous appearance and quite certain to be short lived (Holmes 1883);" "small in size," and "crowded out" (Friesner and Potzger 1931); "few trees," and "slowly dying out" (Oosting and Hess 1956) have been used.

The infestation of HWA in all but one population of eastern hemlock on Delmarva could also be contributing to the overall appearance of low vigor. For example, individuals with narrow crowns and sparse foliage, and the presence of dead standing trunks could be the result of destructive feeding by HWA. Although, the early studies of disjunct populations of eastern hemlock previously mentioned (Holmes 1883; Daubenmire 1931; Friesner and Potzger 1931; Oosting and Hess 1956; Nemeth 1973; Gary Fleming, pers. comm.), report conditions of stress and low vigor without the presence of HWA. Whether the expression of low vigor that currently characterizes most eastern hemlock populations on Delmarva is the result of their disjunct peripheral occurrence, or the infestation of HWA, or both, the presence of HWA is a stress that these populations may not be able to withstand.

On a positive note, reproduction of eastern hemlock on Delmarva is occurring, of the 22 populations sampled, seedlings and saplings were observed in 18 (Table 1).

Hemlock Woolly Adelgid and Control Efforts

HWA was first reported on Delmarva in the early 1990's on ornamental hemlock (Bob Rabaglia, forest entomologist, Maryland Dept. of Ag., and Mike Valenti, Delaware Dept. of Ag., pers. comm.), and by 2002, six counties had become infested (USDA Forest Service 2002): Queen Anne's, MD (1991); Cecil, MD (1992); New Castle County, DE (1993); Caroline, MD (2002); Kent, MD (2002); and Talbot (2002). The earliest HWA infestation reported by the USDA Forest Service (2002) occurred in Queen Anne's County in 1991. This county is centrally located on Delmarva and may have been the source of the infestation for the surrounding counties.

The eastern hemlock population not infested with HWA (Appoquinimink River/Drawyers Creek, New Castle Co., DE), consisted of a single, apparently healthy individual [5 in (12.5 cm) DBH, estimated to be about 6 m (20 ft) tall]. This individual occurred 0.8 km to the east of another much larger population infested with HWA. Quite often, lone individuals of eastern hemlock remain uninfested for longer periods of time than larger populations of eastern hemlock that are infested (personal observation, T. McAvoy).

HWA spreads at an estimated rate of 20 – 30 km (12-19 km) each year (McClure et al. 2001) and wind, birds, deer, and humans help its spread (McClure 1990). HWA feeds at the base of needles and penetrates into the parenchyma cells of the xylem (McClure et al. 2001). In time, needle loss results, as well as an inability to develop new apical buds (McClure 1990; McClure et al. 2001). Little if any new growth is produced on infested branches (McClure et al. 2001). Dieback of major limbs can occur within two years and progresses from the bottom of the tree upward (McClure et al. 2001). Heavy infestations have killed trees in four years, but some trees have survived infestations for more than 10 years with only a sparse amount of foliage at the very top of the crown (McClure et al. 2001). In Delmarva eastern hemlock populations, HWA appeared as small, white cottony balls at the base of needles. Needle loss, and dead or dying limbs were observed in individuals that were infested with HWA.

Some success in combating HWA has been found by using biological control agents. In North America, there are only a few native insect species that prey on HWA and their predation is not enough to make a significant impact on population densities (McClure et al. 2001; Wallace and Hain 2000). Limited and controlled releases of a predatory beetle, *Pseudoscymnus tsugae* (Coleoptera: Coccinellidae) native to Japan, have shown a 47 – 87% reduction in HWA densities in monitored populations (McClure 1999; McClure et al. 2001). Currently, the second author is involved in a project at Mountain Lake, Virginia to control HWA using soil and stem injections of imidacloprid. This is a systemic insecticide that has proven effective against HWA (Silcox 2002). Preliminary results have demonstrated control of HWA on these eastern hemlocks with no harmful effects to non-target organisms. These insecticide applications are intended to slow the harmful effects of HWA until introduced biological control agents (*Pseudoscymnus tsugae*) become abundant enough to control HWA.

Pseudoscymnus tsugae was released in this area in 2000 and a second biological control agent *Laricobius nigrinus* (Zilahi-Balogh et al. 2002) will soon be released. Efforts to control HWA on the Delmarva Peninsula, possibly with imidacloprid applications and release of biological control agents should be initiated in the very near future.

Conclusion

It is hoped that this paper will spark the interest of students and researchers to study populations of eastern hemlock on the Delmarva Peninsula in order to better understand their existence here and to examine ecological differences and relationships that may exist between populations. For example, why does the Sassafras River support the highest number of populations, the highest number of individuals, and the largest diameter trees than any other system sampled? Another example of research needs concerns local land-use history. How has land clearing for agriculture and development impacted native populations of eastern hemlock on Delmarva? Has eastern hemlock on Delmarva ever been an attractive species for timber sales? Research concerning land-use history could add to our overall understanding of the species current status, and perhaps historical status on Delmarva. In addition, soil studies should also be initiated. A better understanding of the soil types associated with each population may provide more insight into the species distribution and frequency of occurrence on Delmarva. Also, comparative studies between disjunct eastern Coastal Plain populations, and populations from within the core of the species range should also be considered; results may find physiological and morphological differences. A comparison of two geographically distinct populations in Wisconsin (Eickmeir et al. 1975) found physiological and morphological differences in seedlings between a disjunct population in the southwest portion of the state, and one from a central population from the northeast portion of the state. Findings indicate that eastern hemlock in Wisconsin exhibits two physiological races correlated with environmental conditions. Seedlings from the southwest population of the state are better adapted to the warmer, drier conditions found in that region and seedlings from the northeast population are better adapted to the cooler, wetter conditions found in that part of the state (Eickmeir et al. 1975). Godman and Lancaster (1990) report no studies regarding the genetics of eastern hemlock in North America. Examining and comparing the potential genetic variability of disjunct Coastal Plain populations with populations from the core of the species range may prove interesting.

Although evidence of reproduction of eastern hemlock populations on Delmarva was observed, there is an apparent lack of overall vigor of these populations, and the presence of HWA in 21 of 22 populations sampled, suggests a trend toward extirpation, therefore, this paper hopes to motivate conservation efforts to protect and enhance eastern hemlock populations on Delmarva and to control HWA. Species conservation depends upon protecting the genetic variability present throughout the range of the species, thus these uncommon disjunct inner Coastal Plain populations should have high value for conservation.

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Literature Cited

Andres, A. S., and C. S. Howard. 1999. Geologic history and hydrogeology of the Great Cypress Swamp. Unpublished report, Delaware Geological Survey, Delaware Natural Heritage Program.

Bormann, F. H., and R. B. Platt. 1958. A disjunct stand of hemlock in the Georgia Piedmont. *Ecology* 39: 16–23.

Brown, R. G., and M. L. Brown. 1972. *Woody Plants of Maryland.* University of Maryland, College Park, MD.

Daubenmire, R. F. 1931. Factors favoring the persistence of a relic association of eastern hemlock in Indiana. *Butler University Botanical Studies* 2: 29–32.

Denny, C. S., J. P. Owens, L. A. Sirkin, and M. Rubin. 1979. The Parsonsburg sand in the central Delmarva Peninsula, Maryland and Delaware. US Geological Survey Professional Paper 1067-B.

Dill, N. H. 1962. An annotated list and study of the geographical affinities of the flora of the Rodney Scout Reservation. Unpublished Thesis, Rutgers State University, New Brunswick New Jersey.

Eickmeier, W., M. Adams, and D. Lester. 1975. Two physiological races of *Tsuga canadensis* in Wisconsin. *Canadian Journal of Botany* 53:940–951.

Flora of North America, Vol. 2. 1993. Pteridophytes and Gymnosperms. Oxford University Press.

Fowler, J. A. 1957. Hemlock on the coastal plain of Maryland. *Atlantic Naturalist* 12:232–234.

Friesner, R. C., and J. E. Potzger. 1931. The ecological significance of *Tsuga canadensis* in Indiana. *Studies in Forest Ecology* 3:133–149.

Godman, R. M., and K. Lancaster. 1990. *Tsuga canadensis* (L.) Carr. Eastern hemlock. Pages 604-612 *in* R. M. Burns and B. H. Honkala (eds). *Silvics of North America: 1. Conifers.* USDA Forest Service, Washington, DC.

Groot, J. J., and R. R. Jordan. 1999. The Pliocene and Quaternary deposits of Delaware: palynology, ages, and paleoenvironments. Delaware Geological Survey, Report of Investigations No. 58.

Hardin, J. W., and A. W. Cooper. 1967. Mountain disjuncts in the eastern Piedmont of North Carolina. *Journal of the Elisha Mitchell Society* 82: 139–150.

Harper, R. M. 1952. Hemlock in Alabama: a supplementary note. *Ecology* 33:128–129.

Harvill, A. M., T. R. Bradley, C. E. Stevens, T. F. Wieboldt, D. M. E. Ware, D. W. Ogle, G. W. Ramsey and G. P. Fleming. 1992. *Atlas of the Virginia Flora.* Virginia Botanical Associates, Burkeville, VA.

Holmes, J.A. 1883. Occurrence of *Abies canadensis* and *Pinus strobus* in central North America. *Journal of the Elisha Mitchell Scientific Society* 1:86–87.

Hotchkiss, A. T., R. R. van Stockum, Jr., and B. van Osdol. 1976. New stations for *Tsuga Canadensis* in southern Indiana. *Castanea* 41:338–343.

Kavanagh, K., and M. Kellman. 1986. Performance of *Tsuga canadensis* (L.) Carr. at the center and northern edge of its range: a comparison. *Journal of Biogeography* 13:145–157.

Lesica, P., and F. W. Allendorf. 1995. When are peripheral populations valuable for conservation? *Conservation Biology* 9: 753–760.

McAvoy, W. A., and K. A. Bennett. 2001. The flora of Delaware, an annotated checklist. Delaware Dept. of Natural Resources and Environmental Control, Dover, Delaware.

McClure, M. S. 1990. Role of wind, birds, deer, and humans in the dispersal of hemlock woolly adelgid (Homoptera: Adelgidae). *Environmental Entomology* 19: 36–43.

McClure, M. S., C. Cheah, and T. C. Tignor. 1999. Is *Pseudoscymnus tsugae* the solution to the hemlock woolly adelgid problem? An early perspective. Pages 89-96 *in* Proceedings: Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA For. Serv. GTR-NE-267.

McClure, M. S., S. M. Salom, and K. S. Shields. 2001. Hemlock woolly adelgid. Forest Health Technology Enterprise Team, U.S. Forest Service, Morgantown, West Virginia. Technical Report: FHTET-2001-03.

McIntosh, R. P. 1950. Pine stands in southwestern Wisconsin. *Transactions of the Wisconsin Academy of Sciences* 40: 243–257.

Nemeth, J. C. 1973. A mountain disjunct hemlock stand in the Piedmont of Virginia. *Castanea* 38:171–174.

Oosting, H. J., and D. W. Hess. 1956. Microclimate and a relic stand of *Tsuga canadensis* in the lower Piedmont of North Carolina. *Ecology* 37: 28–29.

Parshall, T. 2002. Late Holocene stand-scale invasion by hemlock (*Tsuga canadensis*) at its western range limit. *Ecology* 83: 1386–1398.

Segars, C. B., L. C. Crawford, and A. M. Harvill. 1951. The occurrence and distribution of hemlock in Alabama. *Ecology* 32: 149–151.

Sirkin, L. A., C. S. Denny, and R. Meyer. 1977. Late Pleistocene environment of the central Delmarva Peninsula, Delaware-Maryland. Geological Society of America 88:137–142.

Sharpe, G., C. Hendee, and W. Sharpe. 1986. *Introduction to Forestry, 5th edition.* McGraw-Hill Book Co., New York, NY.

Shreve, M., A. Chrysler, F. H. Blodgett, and F. W. Besley. 1910. *The plant life of Maryland.* Maryland Weather Service, Special Publication Vol. III. Johns Hopkins Press, Baltimore.

Silcox, C. A. 2002. Using imidacloprid to control hemlock woolly adelgid. Pages 280-287 *in* B. Onkin, R. Reardon, and J. Lashomb (eds). *Proceedings: Hemlock Woolly Adelgid in the Eastern United States Symposium.* USDA Forest Service.

Souto, D., T. Luther, and B. Chianese. 1996. Past and present status of hemlock woolly adelgid in eastern and Carolina hemlock stands, Pages 9-15 *in* S. M. Salom, T. C. Tigner and R. C. Reardon (eds), *Proceedings of the First Hemlock Woolly Adelgid Review.* USDA Forest Service FHTET 96–10.

Tatnall, R. 1946. *Flora of Delaware and the eastern shore.* The Society of Natural History of Delaware, Wilmington, DE.

Tidestrom, I. 1913. Notes on the flora of Maryland and Virginia. *Journal of the New England Botanical Club* 15:101–104.

Wallace, M. S. and F. P. Hain. 2000. Filed surveys and evaluation of native and established predators of the hemlock woolly adelgid (Homoptera: Adelgidae) in the southeastern United States. *Environmental Entomology* 29:638–644.

Zilahi-Balogh, G., G. L. T. Kok, and S. M. Salom. 2002. Host specificity of *Laricobius nigrinus* Fender (Coleoptera: Derodontidae), a potential biological control agent of the hemlock woolly adelgid, *Adelges tsugae* (Homoptera: Adelgidae). *Biological Control* 24: 192–198.

Appendix 1

The historical and modern day collection record of eastern hemlock on the Delmarva Peninsula (DOV = Claude E. Phillips Herbarium, Delaware State University, Dover, Delaware; PH = Philadelphia Academy of Natural Sciences, Philadelphia, Pennsylvania)

Delaware: New Castle Co., Old Drawyers Church, wooded slope overlooking creek, 4 July 1929, *Tatnall 420* (DOV); N facing slope below Old Drawyers Church, Drawyers Creek/Appoquinimink River, 15 June 1999, *McAvoy 4395* (DOV); N facing slope above Drawyers Creek, 0.5mi E of Old Drawyers Church, 26 September 2001, *McAvoy 5310* (DOV).

Maryland: Caroline Co., Tuckahoe Creek, 2.5mi. S of Hillsboro, 13 October 1935, *Wherry s.n.* (PH); 2.5mi. S of Hillsboro, W bank of Tuckahoe River, 22 August 1936, *Tatnall 3113* (DOV); 2.5mi. S of Hillsboro, below Wayman Wharf, E bank of Tuckahoe Creek, 16 October 1937, *Tatnall 3630* (DOV); N facing slope on Tuckahoe Creek, S of Stony Point, 11 September 1998, *McAvoy 4084* (DOV); N facing slope on Tuckahoe Creek, 2mi. south of Hillsboro, 24 September 2002, *McAvoy 5688* (DOV); W facing slope on Tuckahoe Creek, 1mi. S of Stony Point, 24 September 2002, *McAvoy 5690* (DOV); W facing slope and woodland flats near Stony Point parking area and boat launch, south of Hillsboro, 24 September 2002, *McAvoy* 5708 (DOV); N facing slope on Watts Creek/Choptank River, S of Denton, 23 August 2001, *McAvoy 5249* (DOV); N facing slope on Mill Creek/Choptank River, S of Williston, 23 August 2001, *McAvoy 5251* (DOV); Cecil Co., Little Bohemia Creek, facing N, 3mi. northwest of Warwick, 31 June 1942, *Schmid s.n.* (PH); N facing slope, Little Bohemia Creek, 7 August 1995, *McAvoy 1196* (DOV); N facing slope, Knight Island Peninsula, Back Creek/Sassafras River, SW of Cecilton, 20 May 1997, *McAvoy 2217* (DOV); E

facing slope on Cox Creek/Sassafras River, W of Cecilton, 22 August 2001, *McAvoy 5245* (DOV); Kent Co., N facing slope, Lloyd Creek/Sassafras River, E of Betterton, 30 October 1998, *McAvoy 4222* (DOV); N facing slopes above Turner Creek/Sassafras River, W of Galena, 13 October 2000, *McAvoy 5024* (DOV); N facing slope above Turner Creek/Sassafras River, east of Betterton, 23 September 2002, *McAvoy 5673, 5674* (DOV); N facing slope on Codjus Cove/Still Pond Creek, SW of Betterton, 11 July 2001, *McAvoy 5159*, (DOV); N facing slope on Sassafras River/Fox Hole Landing, E of Fox Hole Landing, NE of Galena, 6 April 2003, *McAvoy 5716* with Jack Holt, (DOV); E facing slope on Sassafrass River/Jacobs Creek, NE of Galena, 3 May 2003, *McAvoy 5748* with Sophia and Ross Elliott, (DOV); N facing slope on Sassafrass River/Wilson Point, NE of Galena, 18 May 2003, *McAvoy 5799* with Sophia and Ross Elliott, (DOV); E facing slope on Sassafras River/Swantown Creek, NE of Galena, 18 May 2003, *McAvoy 5800* with Sophia and Ross Elliott, (DOV); Talbot Co., high banks along Tuckahoe Creek, 3mi. ENE of Cordova, 26 December 1936, *Earle 1315* (PH); E facing slope on Tuckahoe Creek, 3mi. S of Hillsboro, 24 September 2002, *McAvoy 5689* (DOV); East Wye River, 2.5mi SW of Wye Mills, 5 July 1937, *Earle 1550* (PH); N facing slope, Wye East River, N of Wye Landing Lane, 30 October 1998, *McAvoy 4209* (DOV); N facing slope on Pickering Creek/Wye East River, 5 November 2002, *McAvoy 5704* (DOV); Queen Anne's Co., N facing slope on Wye East River, SW of Wye Mills, 30 October 1998, *McAvoy 4210* (DOV); N facing slope on Wye East River, S of Wye Landing, 5 November 2002, *McAvoy 5703* (DOV)

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