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Seasonal phenology and bionomics of clearwing moths in Tennessee

Laura E. Rogers

To the Graduate Council:

I am submitting herewith a thesis written by Laura E. Rogers entitled "Seasonal phenology and bionomics of clearwing moths in Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Entomology and Plant Pathology.

Jerome F. Grant, Major Professor

We have read this thesis and recommend its acceptance:

Charles D. Pless, Mark Windham, Jaime Yanes Jr

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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SEASONAL PHENOLOGY AND BIONOMICS OF CLEARWING MOTHS IN TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Laura E. Rogers
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ABSTRACT

Larvae of clearwing moths (Lepidoptera: Sesiidae) attack and cause serious damage to more than 100 deciduous trees and shrubs in North America. Clearwing moth larvae, commonly referred to as "borers", damage plants by tunnelling beneath the bark while feeding. These borers can destroy vascular tissue and cause loss of vigor, structural weakness, branch dieback or complete girdling and death of trees (Wallace 1945, Schread 1971, Purrington and Nielsen 1977, Potter and Timmons 1983).

With the isolation, characterization and synthesis of the first clearwing moth sex pheromone by Tumlinson and co-workers (1974) additional information concerning borers and their life history could be obtained (Nielsen 1979). Using these sex pheromones, numerous researchers have monitored and reported the seasonal incidence of selected adult Sesiidae (Gentry et al. 1978, Sharp et al. 1978, Neal 1981, Riedl et al. 1985, Meyer et al. 1988).

A clearwing moth, _Synanthedon_ _scitula_ (Harris) (the dogwood borer), is one of the most serious pests of flowering dogwoods, _Cornus_ _florida_ L., in the eastern United States, especially in Tennessee (Pless and Stanley 1967, Williams et al. 1985). Due to the availability of a synthetic pheromone attractive to dogwood borer and the lack of information available on clearwing moths in

Tennessee, a two-year study was conducted to monitor the seasonal incidence of clearwing moths in eastern and middle Tennessee and to assess infestation levels of dogwood borer on dogwood in commercial nursery, urban, and forest habitats.

Eight species of clearwing moths were collected during 1987-1988 and included: *Podosesia syringae* (Harris), lilac borer; *Paranthrene simulans* "palmii" (Grote), an oak borer; *Synanthedon scitula*, dogwood borer; *Synanthedon rhododendri* (Beutenmüller), rhododendron borer: *Synanthedon exitiosa* (Say), peachtree borer; *Synanthedon fatifera* Hodges, a viburnum borer; *Synanthedon acerni* (Clemens), maple callous borer; and *Synanthedon decipiens* (Hy. Edwards), a borer of cynipid galls on oak.

Lilac borers were the most abundant species collected during this two-year study and represented ca. 70% of the moths collected in the nursery and urban habitats and ca. 41% of the moths collected in the forest habitat. The dogwood borer represented ca. 10% of the moths collected in the nursery and urban habitats but was not collected in the forest habitat. Approximately 45% of the moths collected in the forest habitat were rhododendron borers. The high percentage of rhododendron borers collected in the forest habitat is a result of the large number of rhododendrons found in the forest areas sampled.

The dogwood borer exhibited a bimodal period of emergence with the first peak occurring in mid-May and the second in the beginning of August. This information is important from a managerial standpoint and suggests the application of two properly timed chemical treatments for the control of dogwood borer. The highest infestation level (ca. 60%) of dogwood borer on dogwood was found in the urban habitat. The high infestation level in the urban habitat is due to adverse environmental stresses placed on the tree growing in an unnatural environment. Dogwood trees planted as ornamentals in the urban habitat are usually planted in full sun and subject to mechanical injuries (e.g. damage by lawnmowers) which increase the susceptibility of the tree to borer infestation (Potter and Timmons 1983). All nursery blocks examined were infested with dogwood borer and percent infestation averaged ca. 7%. Approximately 1% of the trees examined in the forest habitat were infested with dogwood borer.

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CHAPTER I

INTRODUCTION

The clearwing moth family (Lepidoptera: Sesiidae) consists of approximately 170 genera with more than 1000 species described worldwide (Duckworth and Eichlin 1973). In North America, the first comprehensive review of clearwing moths was provided in 1901 by Beutenmüller and later expanded and revised by Engelhardt (1946). Both reviews provided information on the life histories of clearwing moths in North America. Duckworth and Eichlin are currently completing a systematic study of the sesiids of the Western Hemisphere (Eichlin, personal communication). One of the major objectives of their study is to provide a more precise description, through detailed morphological comparisons, of the species of Sesiidae and to establish a system of classification that would accurately reflect the relationships among the taxa of this family (Duckworth and Eichlin 1977).

Sesiid adults are primarily diurnal, and have become modified structurally and behaviorally to resemble various Hymenoptera. Adults are characterized by their narrow, transparent wings, clavate or filiform antennae and elongate, slender abdomen which is tapered posteriorly and often narrowed at the base (Duckworth and Eichlin 1974). The abdomen is often banded with orange or yellow, and the legs are usually tufted with yellow scales to further mimic certain Hymenoptera.

Eggs of sesiid species are deposited singly on or near the host plant. Eggs are ovate, disc-shaped, flat or slightly concave ventrally, and are textured with hexagonal ridges on the surface (Duckworth and Eichlin 1977). Incubation time of the eggs varies among species and is dependent upon temperature.

Sesiid larvae, upon hatching, bore into the host plant and are commonly referred to as "borers". The eruciform larvae are pale white, without body markings except for yellow pigmentation on the head and prothoracic shield (Duckworth and Eichlin 1977). Prior to pupation, the larva excavates a tunnel to the surface leaving only a thin layer of bark and forms a pupal case (Duckworth and Eichlin 1974). Later, the pupa penetrates the thin covering of bark and extrudes a portion of its abdomen. Finally, the pupal skin splits and the adult moth emerges. Life cycles are usually completed in one year but some sesiids require more than one year to complete their life cycle.

Clearwing borers attack and cause serious damage to more than 100 deciduous trees and shrubs in North America. Borers damage woody plants by tunnelling beneath the bark while feeding. Clearwing borers can destroy vascular tissue and cause loss of vigor, structural weakness, branch dieback or complete girdling and death of trees (Snapp and Thomson 1943, Wallace 1945, Schread 1971, Purrington and Nielsen 1977, Potter and Timmons 1981, 1983a).

Several species of clearwing moths are serious pests of trees and shrubs in the southeastern United States. The most important species include Podosesia syringae Harris, lilac borer; Paranthrene simulans "palmii" (Edwards), oak borer; Synanthedon rhododendri (Beutenmüller), rhododendron borer; Synanthedon exitiosa (Say), peachtree borer; and Synanthedon scitula (Harris), dogwood borer. These borers can cause economic damage to trees and shrubs that are grown as ornamentals or for wood production.

Lilac borers resemble Polistes wasps in appearance and are serious pests of lilac, Syringa vulgaris L.; privet, Ligustrum amurense Carr; and species of ash, Fraxinus, in commercial nurseries and in the urban landscape (Potter and Timmons 1983b). Damage to nursery-grown lilacs can exceed $12,000/ha during each cropping cycle (Nielsen and Balderston 1973). This species is found throughout temperate North America from the maritime provinces of Canada west to Saskatchewan and Utah, and south to Florida and Texas, and has been studied by numerous researchers throughout North America (Grayson 1943, Appleby 1973, Solomon 1975, 1983a,b, Purrington and Nielsen 1977, 1979, Dix et al. 1978, 1979, Nielsen and Purrington 1974, 1978a, Nielsen et al. 1980, Timmons and Potter 1981, Potter and

Timmons 1983b, Santamour and Steiner 1986, Santamour 1987, Meyer et al. 1988).

The oak borer is a serious pest of red oak, Quercus rubra L., and also attacks other oak species (Solomon and Morris 1966, Solomon 1985). This species bores into the base of oaks producing galleries that can encourage the growth of rot- and stain-producing fungi that degrade the value of the log (Solomon and Morris 1966).

The rhododendron borer is found along the Atlantic Coast from New York to South Carolina and inland to Ohio (Neal 1981). Larvae of this borer cause serious damage to rhododendrons, Rhododendron spp., and mountain laurel, Kalmia latifolia L., by tunnelling in the trunk, branches, and stems (Engelhardt 1946). Studies on the life history and biology of the rhododendron borer have been conducted by Neal (1981, 1984) in Maryland.

The peachtree borer is an important pest in peach orchards and in landscapes where peach, Prunus persica (L.) Batsch, and other Prunus spp. are found (Potter and Timmons 1983c). One of the earliest detailed descriptions of the peachtree borer and the damage it causes to peach was provided by Slingerland (1899). More recently, peachtree borer research has been directed primarily towards monitoring adult flight activity and the disruption of mating communication through the use of pheromone-baited traps and dispensers (Tumlinson et al. 1974, McLaughlin et al. 1976, Gentry et al. 1977, 1978, Sharp et al. 1978, McLaughlin 1979, Yonce and Pate 1979, Yonce 1981, Johnson and Mayes 1983).

One of the most important insect pests of flowering dogwood, Cornus florida L., is the dogwood borer (Underhill 1935, Wallace 1945, Pless and Stanley 1967, Potter and Timmons 1981, 1983a, Riedl et al. 1985, Williams et al. 1985). Williams et al. (1985) reported that the dogwood borer is the most destructive insect pest of the flowering dogwood in Tennessee. Larvae, which feed in the phloem and cambium of the tree, can partially or completely girdle the trunks or limbs of dogwood trees (Potter and Timmons 1983a). The dogwood borer, native to North America, occurs wherever the flowering dogwood is found from southeastern Canada to Florida and west to the Mississippi River (Wallace 1945). In addition to dogwood, many other hosts may be attacked by the dogwood borer including oak, hickory, chestnut, hazel, cherry, apple, willow, beech, myrtle, pine, mountain ash, birch, ninebark, bayberry, rattan vines, and pecan (Pless and Stanley 1967).

The dogwood borer adult was first described and designated Aegeria scitula by Harris in 1839. A more detailed description of the adult moth was later provided by Beutenmüller (1901). The adult dogwood borer is blue/black with a metallic sheen and the thorax and abdomen are both characterized with yellow markings. The thorax has a dorsoventral yellow line and ventral yellow spot, and the abdomen is marked dorsally with a yellow band on the second and fourth segments. The fourth abdominal band is approximately twice as wide as the second abdominal band and extends to cover the ventral surface of the abdomen (Wallace 1945). The female moth, unlike the male, is also marked with yellow ventrally on abdominal segments five and six (Pless and Stanley 1967). The antennae are black and the palpi yellow; in the male the palpi are tipped with black. A stiff collar of hairs is located at the base of the head and is yellow dorsally but becomes white laterally around the base of the eyes. The femora of both the male and female are blue/black but the remaining segments of the legs are yellow. The anal tuft is black and marked laterally with yellow and is fan-shaped in the male and brushlike in the female. The narrow forewings are transparent; borders and discal mark are blue black. The length of the moth is 18-22mm.

The pale-white larva of the dogwood borer was originally described by Dyar (1894). MacKay (1968) revised the North American Sesiidae based on late-instar larvae and provided the following distinguishing characteristics for larvae of the dogwood borer: head about as long as broad; prothoracic shield with a broken line of pigment; spiracle on prothorax small; crochets moderately developed, not much reduced in number on prolegs of segment six; length of the final instar, 14mm.

Several of the earliest descriptions of the life history of the dogwood borer related to the injury it caused to pecan (Herrick 1904, Leiby 1925). Early reports indicated that the dogwood borer developed primarily in galls and other malformations on pecan (Herrick 1904). Engelhardt (1932), however, suggested that the dogwood borer had since changed its habits to become a bark and cambium pest. Leiby (1925) reported that the borer was found in every commercial pecan orchard in the state of North Carolina. Tunnels excavated by the borer were found under the bark of the tree, around small branches where they were attached to the trunk, and in the budded patches which had been inserted on cut-back seedling trees.

Additional early studies on the feeding habits of the dogwood borer and the injury produced are mentioned briefly in numerous papers and texts (Felt 1906, 1926, Engelhardt 1932, Herrick 1935, Langford and Cory 1939). Engelhardt (1932) recognized that the feeding habits of the dogwood borer were controlled by the physical condition of the plant. For example, he found that infestation sites of the dogwood borer were in areas on the dogwood that had been previously injured by other insects or pathogens. Larvae enter the inner bark of the tree through an opening on the trunk of the tree. The larva excavates a feeding tunnel underneath the bark and forces frass out of the tunnel as it feeds. As the larva develops, the feeding tunnel is widened.

Little information is available on the life history of the dogwood borer (Underhill 1935, Wallace 1945, Pless and Stanley 1967). During the winter, larvae can be found in the tunnel (Underhill 1935). In the spring or summer before pupation, the larva excavates an opening to the outer bark and forms a pupal cell, although some larvae occasionally leave their tunnels and form cocoons in the loose soil near the base of the tree (Wallace 1945). The duration of the prepupal and pupal stages ranges from two to four weeks (Underhill 1935), dependent upon temperature (Wallace 1945). Prior to emergence, the pupa moves toward the thin surface of the bark and extrudes itself as far as the third or fourth abdominal segments. The dorsum of the head and thorax of the pupal skin splits and the adult emerges (Wallace 1945).

Periods of adult emergence and activity vary according to range of distribution (Underhill 1935, Wallace 1945, Pless and Stanley 1967, Potter and Timmons 1983a, Riedl et al. 1985, Warner and Hay 1985). Underhill (1935) found that the emergence period for dogwood borers in Virginia was from mid-May until the end of September. In

Connecticut, the emergence period for dogwood borers was also noted to occur from May to September (Wallace 1945). An early report from Tennessee speculated that dogwood borer emergence occurs from late April until the second week of October (Pless and Stanley 1967). In recent studies in Kentucky, emergence of adult dogwood borers was reported to occur from 12 to 26 May until early October (Potter and Timmons 1983a). Riedl and coworkers (1985) reported that emergence of dogwood borer from apple in western New York occurred from mid-June to September. Flight activity of dogwood borers in central Ontario has been reported to occur from late June until early August (Warner and Hay 1985).

Mating or oviposition has not been observed in past studies on the dogwood borer (Wallace 1945, Pless and Stanley 1967). Four eggs, positioned singly but fairly close together, were found on dogwood in laboratory studies (Wallace 1945). In cage studies conducted in the laboratory, only a small number of eggs were laid on dogwood stems but most were found to be infertile (Underhill 1935). Underhill reported that the incubation period for eggs of the dogwood borer is eight to nine days. Additional studies have also reported that the incubation period for dogwood borer eggs is eight to nine days at 80°F (Pless and Stanley 1967). Pless and Stanley (1967) examined small sections of dogwood tree trunks under a microscope to observe eggs of the dogwood borer. They found that eggs were laid adjacent to wounds or on the frass produced by other borers.

The potential threat of the dogwood borer to dogwood nursery production was first recognized by Underhill (1935) in Virginia. In June of 1931, 15-19% of the trees in one block of 18,000 dogwood trees in Virginia was found to be infested by the dogwood borer (Underhill 1935). Later in October, the infestation in the same dogwood block had increased to 39%. Underhill estimated that 4,000 trees had been destroyed or seriously damaged by dogwood borers.

The dogwood borer is a problem to both nursery production and to trees grown for ornamental purposes in the urban landscape. The popularity of the dogwood tree in the eastern United States is evident by its widespread use as an ornamental (Potter and Timmons 1983a). In Tennessee, dogwood trees are grown for commercial nursery production and are the most popular tree sold by nurserymen. Dogwood trees account for approximately 16% of the total number of trees grown for commercial purposes in Tennessee with an annual estimated value to nurserymen of 24 million dollars (Day, personal communication). The impact of dogwood borers on dogwood production in the commercial nursery is unknown. Additional information concerning the life history of dogwood borers and their impact on dogwood trees is necessary before a suitable pest management program for suppression of borers can be developed and implemented.

With the isolation, characterization and synthesis of the first clearwing moth sex pheromone by Tumlinson and coworkers (1974) additional information concerning borers and their life history could be obtained (Nielsen 1979). Research was conducted utilizing pheromone-baited traps to monitor adult seasonal incidence and activity of selected species of clearwing borers. This method for studying clearwing moth flight activity provides information useful for more accurate timing of insecticidal sprays for control of borer populations (Nielsen 1978a,b, Nielsen and Purrington 1978b, Neal 1981, Potter and Timmons 1983a).

Species of Sesiidae have been found to differ only slightly in chemicals used as mating attractants. Nielsen and Balderston (1973) reported intergeneric sex attraction among the Sesiidae and conducted field tests utilizing traps baited with virgin female lilac borers and virgin female ash borers, Podosesia aureocincta Purrington and Nielsen. Those traps baited with lilac borers captured members of the genus Paranthrene and those baited with ash borers captured peachtree borers (genus Synanthedon).

Many of the Sesiidae have been shown to be attracted to individual isomers or isomeric mixtures of 3,13-octadecadien-l-ol acetate (ODDA) (Nielsen et al. 1975). Several isometric blends have been evaluated for their effectiveness as attractants and baits for clearwing moth adults by numerous researchers (Nielsen et al. 1975, 1979, Nielsen and Purrington 1978a, Sharp et al. 1978, Sharp and Eichlin 1979).

Because of the availability of a pheromone attractive to sesiids and the lack of information available on adult seasonal incidence of sesiids in Tennessee, a study was initiated to address these issues. The objectives of this research were to:

1) determine seasonal incidence and abundance of adult Sesiidae in Tennessee;

2) examine and determine infestation levels of dogwood borer in dogwood nursery blocks;

3) determine infestation levels of dogwood borer in forest and urban landscape settings; and

4) evaluate the influence of selected management and cultural practices on borer infestation in commercial nurseries.

CHAPTER II

SEASONAL INCIDENCE OF CLEARWING MOTHS IN COMMERCIAL NURSERY, URBAN, AND FOREST HABITATS IN TENNESSEE

i. INTRODUCTION

Larvae of clearwing moths (Lepidoptera: Sesiidae) may seriously damage or kill trees and shrubs in commercial nurseries and urban landscapes. The clearwing moth complex can be one of the most difficult pest groups to control (Nielsen and Purrington 1978b). Borers of economic importance to nursery and timber producers, as well as to private homeowners, include species of *Podosesia* Möschler, *Paranthrene* Hübner and *Synanthedon* Hübner (Solomon et al. 1981).

A clearwing moth, *Synanthedon scitula* (Harris) (the dogwood borer), is one of the most serious pests of flowering dogwood, *Cornus florida* L., in the eastern United States, especially in Tennessee where dogwoods are grown for nursery production (Pless and Stanley 1967, Williams et al. 1985). Dogwood borer larvae feed in the phloem and cambium of the tree and can partially or completely girdle the trunks or limbs (Potter and Timmons 1983a,b). Control methods, primarily chemical applications of Dursban and Lindane, are usually directed at the larva. Because the larva is vulnerable to residual insecticides only from the time of hatching to penetration of the bark tissue (Nielsen 1978b), it is essential to implement control tactics at the appropriate time for maximum reduction of the pest population.

Synthetic sex attractants have enabled researchers to obtain additional information related to the biologies of Sesiidae (Nielsen 1978a). Pheromone traps, used as monitoring devices, can aid in determining periods of peak adult activity. This information can then be used to more accurately time insecticide applications for control of borer populations (Potter and Timmons 1983c). The seasonal activity of selected adult Sesiidae as determined by pheromone trap catches has been reported by numerous researchers (Gentry et al. 1978, Nielsen and Purrington 1978b, Sharp et al. 1978, Sharp and Eichlin 1979, Yonce and Pate 1979, Neal 1981, Solomon et al. 1981, Yonce 1981, Adler 1983, Johnson and Mayes 1983, Neal and Eichlin 1983, Potter and Timmons 1983a,b, Riedl et al. 1985, Snow et al. 1985, Warner and Hay 1985, Meyer et al. 1988).

Few studies have been conducted on the seasonal incidence of clearwing moths in Tennessee (Pless and Stanley 1967, Butler 1931, 1932). In 1987, a two-year study was initiated to monitor the seasonal incidence of selected clearwing moths in three types of habitats (commercial nursery, urban landscape, and forest) in Tennessee with special emphasis on the dogwood borer.

ii. MATERIALS AND METHODS

Flight activity of clearwing moths was assessed from April 1987 to September 1988 by monitoring 22 pheromone traps placed in commercial nursery, urban, and forest habitats at nine locations in eastern and middle Tennessee (Table 1, Figure 1). Each pheromone trap consisted of one Pherocon 1C sticky trap (Trece, Salinas, California), a two-sided trap with a removable trap bottom, baited with one rubber septa. Each rubber septa was impregnated with 250ug of 99% (Z,Z)-3,13 octadecadien-1-ol acetate (Z,Z-ODDA), obtained from J. H. Tumlinson, Gainesville, Florida, and each septa was placed in the middle of the trap suspended from the top of the trap by a thin piece of wire. Previous studies have documented the effectiveness of Z,Z-ODDA as a bait for attracting 12 species of clearwing moths including the dogwood borer (Potter and Timmons 1983a,b, Snow et al. 1985). Traps were placed 1.5m high in each study area and monitored weekly from early April through mid-October and monthly from mid-October to early April for each year. On each sampling date, trap bottoms were removed and replaced with new bottoms coated with sticky material. Trap bottoms were taken to the laboratory where moths were removed and cleaned in hexane. Each moth was

Table 1. Site characteristics for each pheromone-trapping area in eastern and middle Tennessee

Habitat	County	Trees	Age [1] (years)
Commercial Nursery	Warren [2]	Dogwood	10-12
	Warren	Dogwood	8-15
	Warren	Dogwood	3-4
	Warren	Dogwood	4-5
	Warren	Apple	4
	Blount [3]	Dogwood	3-15
Urban	Knox [3]	Dogwood/mixture	variable
	Knox	Dogwood/mixture	variable
Forest	Blount	Mixed Deciduous	variable

[1] Age was determined by the number of years the tree had been in the field.

[2] Middle Tennessee area

[3] Eastern Tennessee area

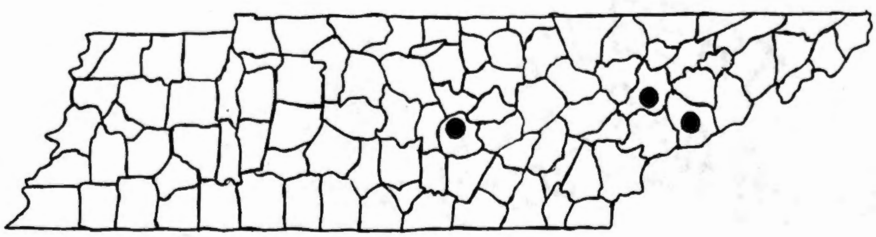

Figure 1. Location of sampling sites in eastern and middle Tennessee.

removed from the trap bottom with fine forceps and placed in a hexane wash for at least 15 minutes (in a few cases, as long as 2 hours) until identifying characteristics became visible. The moths were then examined under a dissecting microscope and identified. Dr. J. Wendell Snow and Kathy Scarborough of the USDA Fruit and Tree Nut Research Laboratory in Byron, Georgia, assisted with the identification of the moths. Traps were baited with fresh septa in April 1987 and again in April 1988 at the beginning of the second season. Previous field studies with Z,Z-ODDA have demonstrated that this pheromone, impregnated on rubber septa, is attractive to clearwing moth adults for as long as three years (Tumlinson 1979).

Five commercial nurseries in Warren County were chosen as study sites in middle Tennessee. Warren County has the highest concentration of commercial nurseries in the state. Two traps were placed in each of four blocks of dogwood trees. Blocks ranged in size from 50 to more than 1000 white and/or pink dogwood trees per block. Age of the dogwood trees ranged from 3 to more than 15 years in the field (Table 1). To note possible late season emergence of dogwood borer from apple as suggested by Potter and Timmons (1983a), two traps were placed in one block (n=1000) of 4-year-old apple trees. One dogwood block (n=100) in a commercial nursery in Blount County was chosen as a study site for monitoring flight activity of sesiids in eastern

Tennessee. Three traps were placed in this block which contained pink and white dogwood trees (3 to 15 years old).

Three pheromone traps were placed in the Great Smoky Mountains National Park, Blount County, in eastern Tennessee to provide information on adult sesiids, especially dogwood borer, in a forest habitat. Traps were placed in a mixed deciduous forest in areas where dogwood trees were found in the understory of the forest.

Study sites in Knox County chosen for trapping in the urban landscape habitat included the Agricultural Campus at the University of Tennessee and a large residential area (Sequoyah Hills). Three traps were placed at each of these two locations in areas where dogwood trees had been planted as ornamentals.

iii. RESULTS AND DISCUSSION

SPECIES COMPOSITION

In 1987 and 1988, eight species of clearwing moths were collected from pheromone-baited traps in commercial nursery, urban, and forest habitats in Tennessee. The sesiid species trapped included *Podosesia syringae* (Harris), the lilac borer, *Paranthrene simulans* "palmii" (Grote), an oak borer, *S. scitula* (Harris), *Synanthedon rhododendri* (Beutenmüller), the rhododendron borer, *Synanthedon exitiosa* (Say), the peachtree borer, Synanthedon fatifera Hodges, a viburnum borer, Synanthedon acerni (Clemens), the maple callous borer, and Synanthedon decipiens (Hy. Edwards), a borer that inhabits the galls of cynipid wasps on oak.

Approximately 65% of the total number of sesiid moths collected in 1987 and 1988 in Tennessee were P. syringae (Table 2). Paranthrene simulans "palmii", S. scitula, and S. rhododendri were also collected in large numbers and represented ca. 12, 9, and 8%, respectively, of the total number of moths collected in 1987 and 1988. Approximately 5% of the moths collected were S. exitiosa. Synanthedon fatifera, S. acerni and S. decipiens were collected in low numbers and each represented less than 0.5% of the moths collected.

In the nursery habitat in middle Tennessee, ca. 71% of the moths collected in 1987 and 1988 were P. syringae (Table 3). Synanthedon scitula and P. simulans "palmii" each represented ca. 10-12% of the moths collected in the nursery habitat. Synanthedon exitiosa represented ca. 6% of those moths captured in the nursery habitat and S. rhododendri was collected in low numbers, ca. 0.4%, in this habitat.

Podosesia syringae, P. simulans "palmii" and S. scitula represented ca. 70, 12, and 11%, respectively, of the total number of moths collected in the urban habitat in 1987 and 1988 (Table 3). The percent composition of these

Table 2. Total number and percent composition of male Sesiidae collected in pheromone-baited traps in eastern and middle Tennessee during 1987 and 1988

Species	n	Percent Composition
Podosesia syringae	4301	64.89
Paranthrene simulans "palmii"	764	11.53
Synanthedon scitula	613	9.25
Synanthedon rhododendri	542	8.18
Synanthedon exitiosa	359	5.42
Synanthedon fatifera	24	0.36
Synanthedon acerni	8	0.12
Synanthedon decipiens	7	0.10
Other[1]	10	0.15

[1] Includes borer adults that have not been positively identified.

Table 3. Total number and percent composition of male Sesiidae collected in pheromone-baited traps in commercial nursery, urban, and forest habitats in eastern and middle Tennessee during 1987 and 1988

	Habitat					
	Nursery		Urban		Forest	
Species	n	%	n	%	n	%
Podosesia syringae	2457	71.01	1041	70.48	474	42.10
Paranthrene simulans "palmii"	404	11.68	181	12.30	140	12.40
Synanthedon scitula	357	10.32	162	10.97	0	0.00
Synanthedon rhododendri	12	0.35	46	3.10	483	42.90
Synanthedon exitiosa	220	6.36	39	2.60	0	0.00
Synanthedon fatifera	0	0.00	0	0.00	24	2.10
Synanthedon acerni	1	0.03	1	0.07	6	0.50
Synanthedon decipiens	7	0.20	0	0.00	0	0.00
Other[1]	2	0.06	7	0.47	0	0.00

[1] Includes borer adults that have not been positively identified.

moths in the urban habitat was similiar to that found in the commercial nursery habitat and may be a result of the similarity of the type of plants found in each habitat. The percentage of S. rhododendri found in the urban habitat (ca. 3%) was ca. 7.5x greater than that found in the commercial nursery (ca. 0.4%). The higher number of S. rhododendri found in the urban habitat may be attributed to the abundance of rhododendrons in the urban landscape. As expected, the percentage of S. exitiosa found in the urban habitat (ca. 3%) was lower than that found in the commercial nursery habitat (ca. 6%) because peach trees are not commonly planted in the urban landscape in eastern Tennessee.

The greatest difference among the compositions of the moths in the three habitats was found in the forest habitat (Table 3). Synanthedon rhododendri represented ca. 43% of the total number of moths collected in this habitat. The high percentage of S. rhododendri in the forest habitat compared to the percentages found in the commercial nursery and urban habitats may be the result of the prevalence of rhododendrons and mountain laurel in the forest. Podosesia syringae was also commonly collected in the forest and represented ca. 42% of the moths collected in that habitat. Synanthedon scitula was not collected in the forest habitat. Native dogwoods are less susceptible to invasion by the dogwood borer than dogwoods planted as ornamentals in the urban landscape or those dogwoods grown for mass production in the commercial nursery since entry sites for borers commonly occur as a result of mechanical injury to the tree. Dogwoods planted as ornamentals are often planted in full sun which also increases the susceptibility of the tree to borer infestation (Potter and Timmons 1981). Wallace (1945) reported that the sesiids are "light-loving" insects and, therefore, may prefer oviposition sites on trees found in full sun. *Synanthedon exitiosa* was not collected in the forest habitat and may be due to this borer's preference for cultivated peach over the native *Prunus* spp. *Synanthedon fatifera* was collected in the forest habitat (ca. 2%) although it was not collected in the commercial nursery or urban habitats. *Synanthedon fatifera* is a pest of viburnums which are commonly found in the forest.

SEASONAL INCIDENCE

Podosesia syringae was the first species collected in 1987 and 1988 and emerged from the middle of April to the middle of July (Figure 2). In 1987, adult activity peaked in late April im middle Tennessee and mid-May in eastern Tennessee and tapered off by the beginning of July (Figures 3-6). In 1988, adult activity was similiar in all habitats in eastern and middle Tennessee, peaking in early to mid-

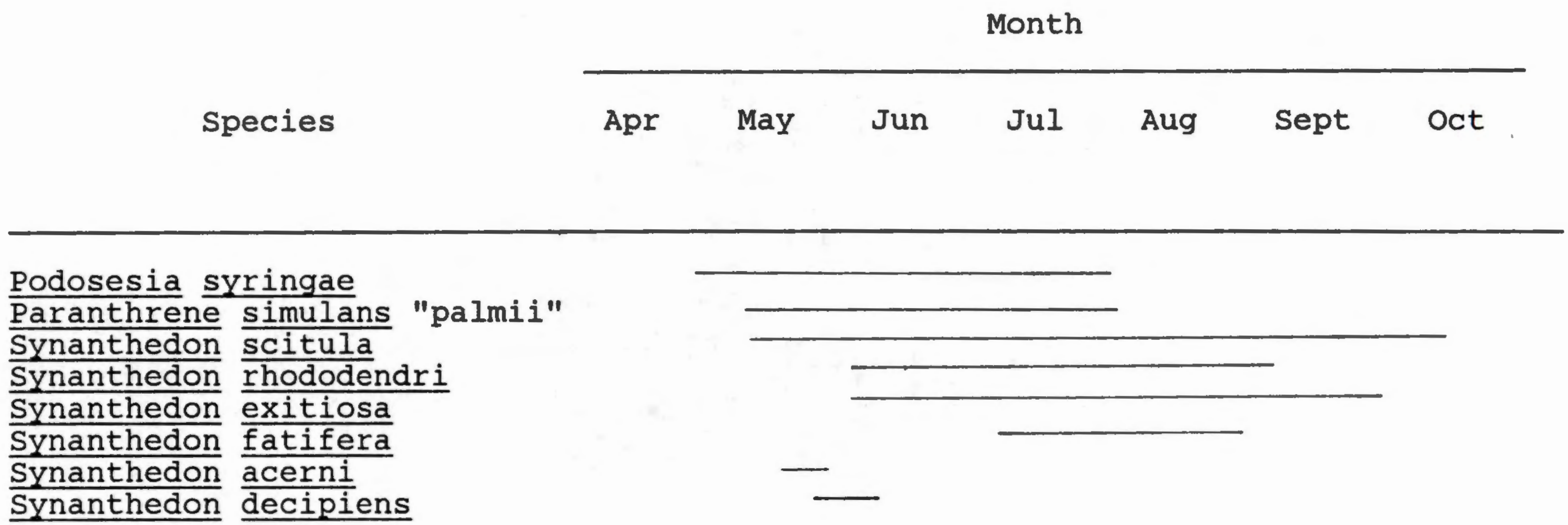

Figure 2. Seasonal incidence of male Sesiidae collected in pheromone-baited traps in eastern and middle Tennessee during 1987 and 1988.

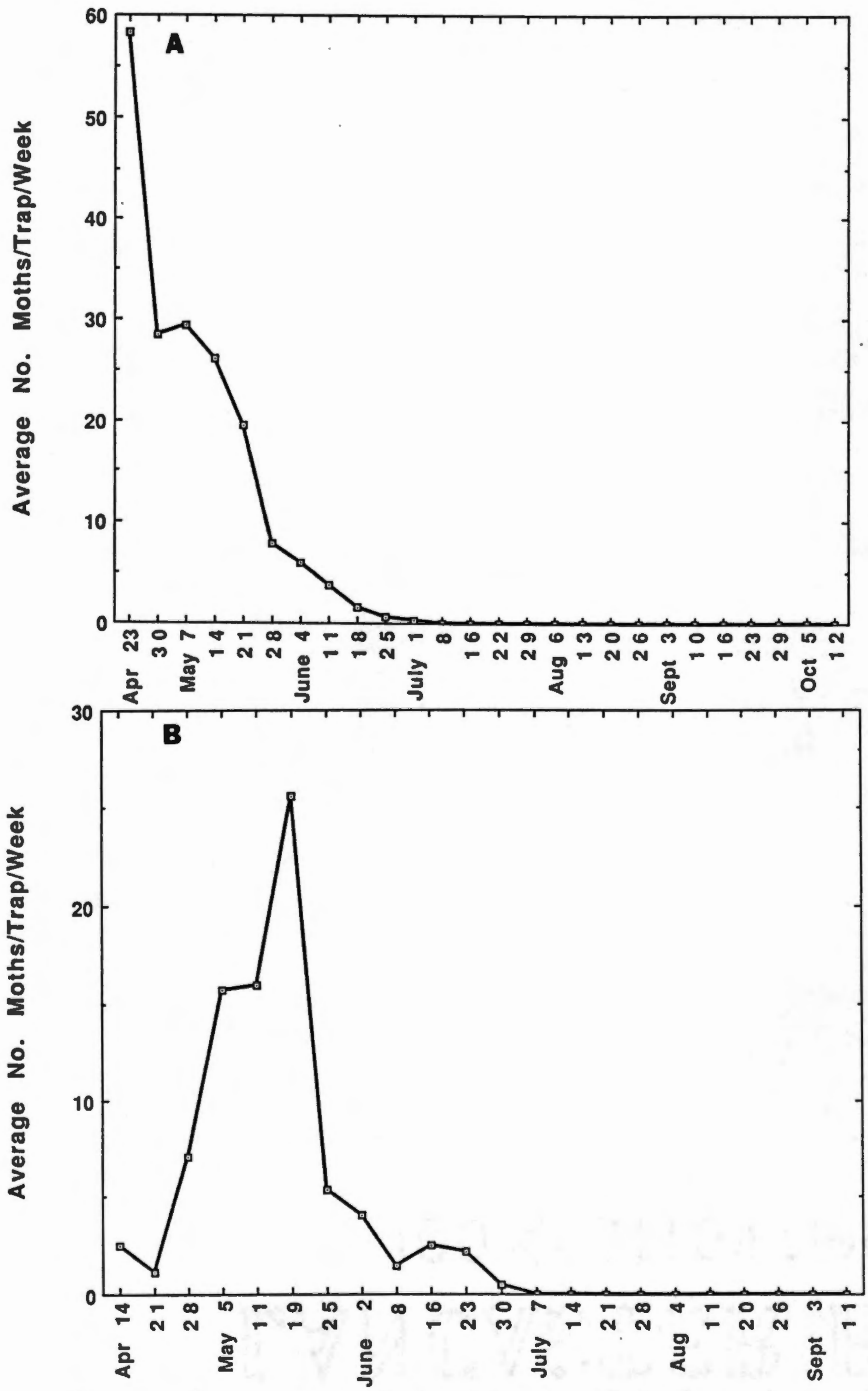

Figure 3. Seasonal incidence of *Podosesia syringae* in commercial nurseries in middle Tennessee during (A) 1987 and (B) 1988.

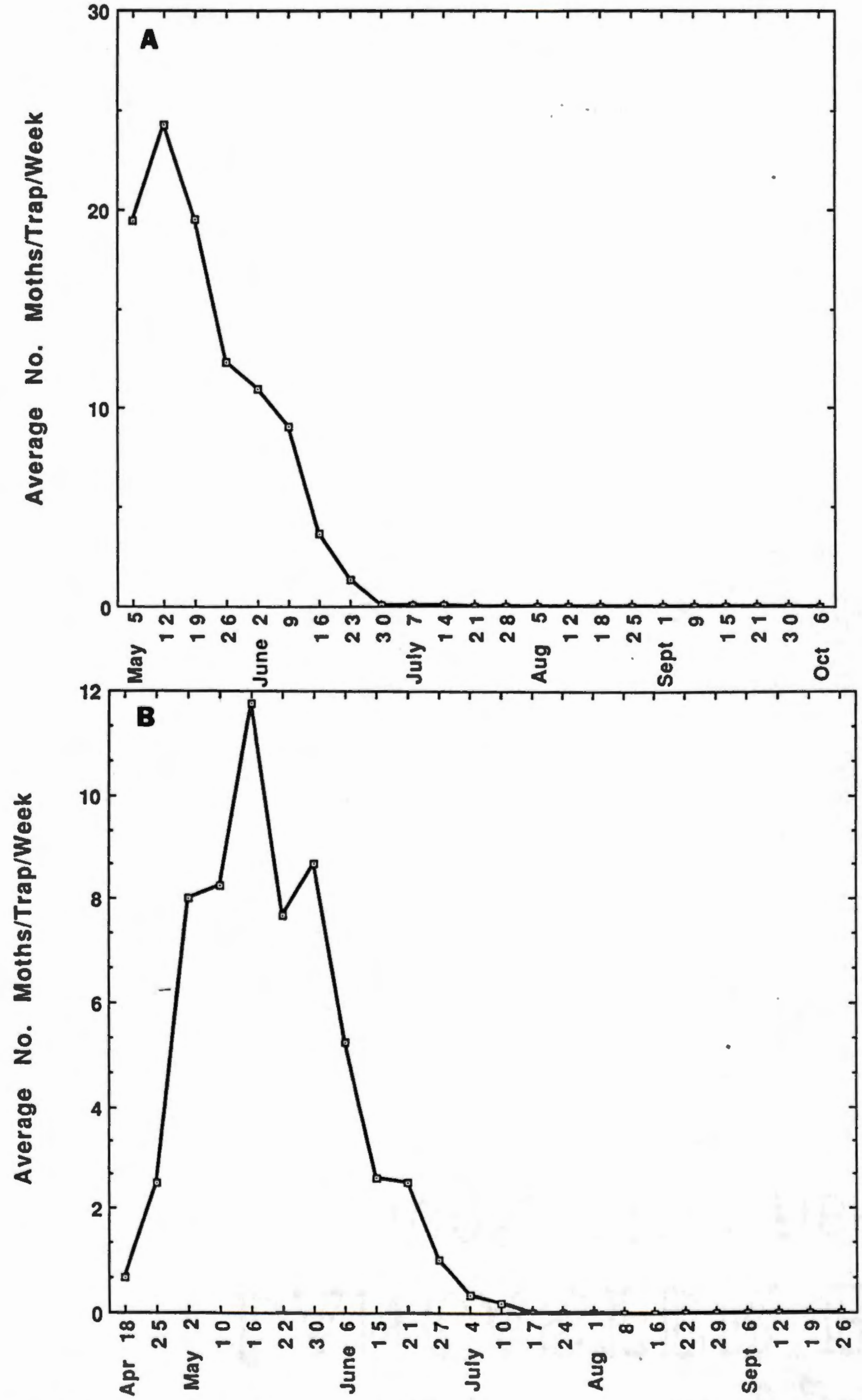

Figure 4. Seasonal incidence of Podosesia syringae in eastern Tennessee (combined for all habitats) during (A) 1987 and (B) 1988.

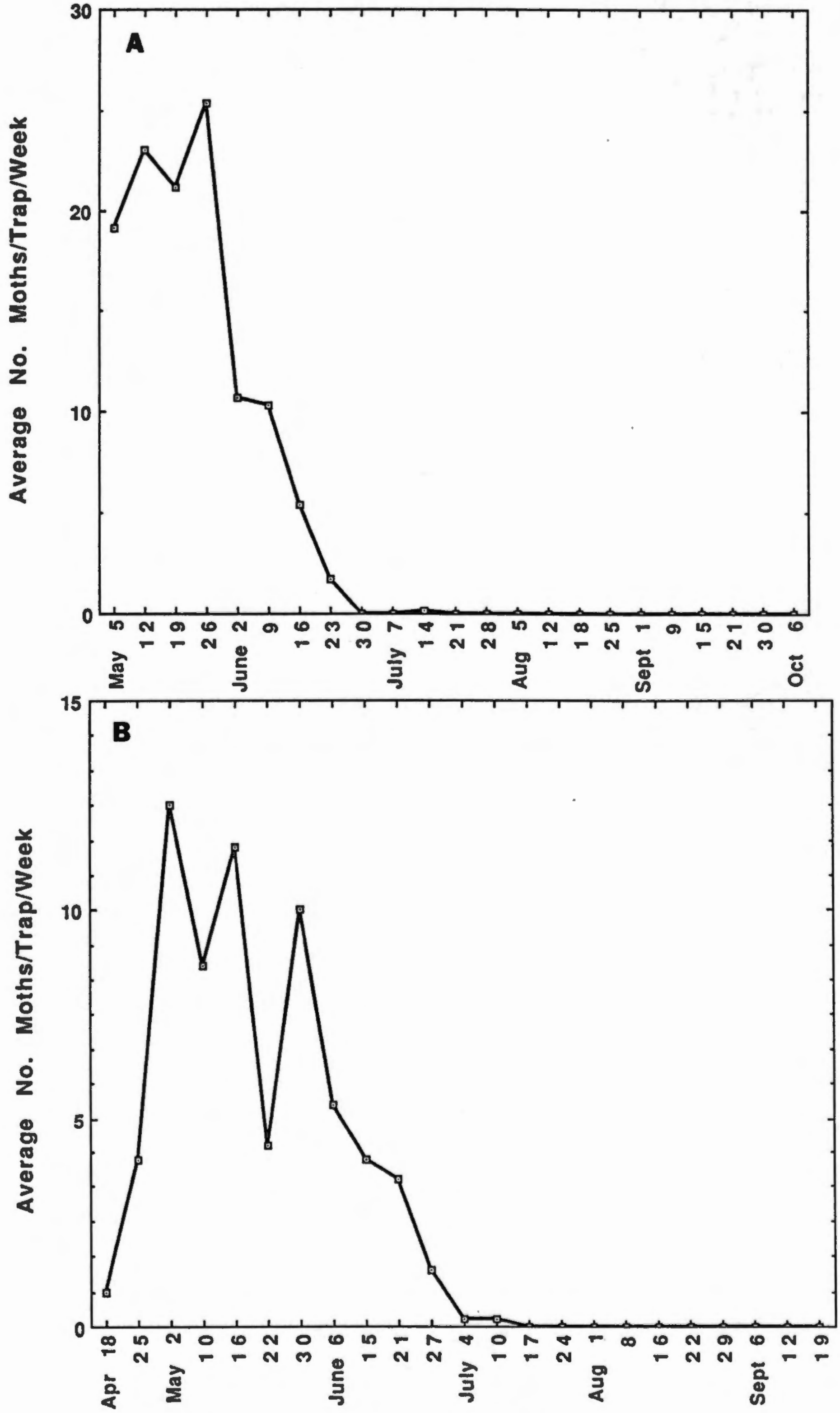

Figure 5. Seasonal incidence of Podosesia syringae in the urban habitat in eastern Tennessee during (A) 1987 and (B) 1988.

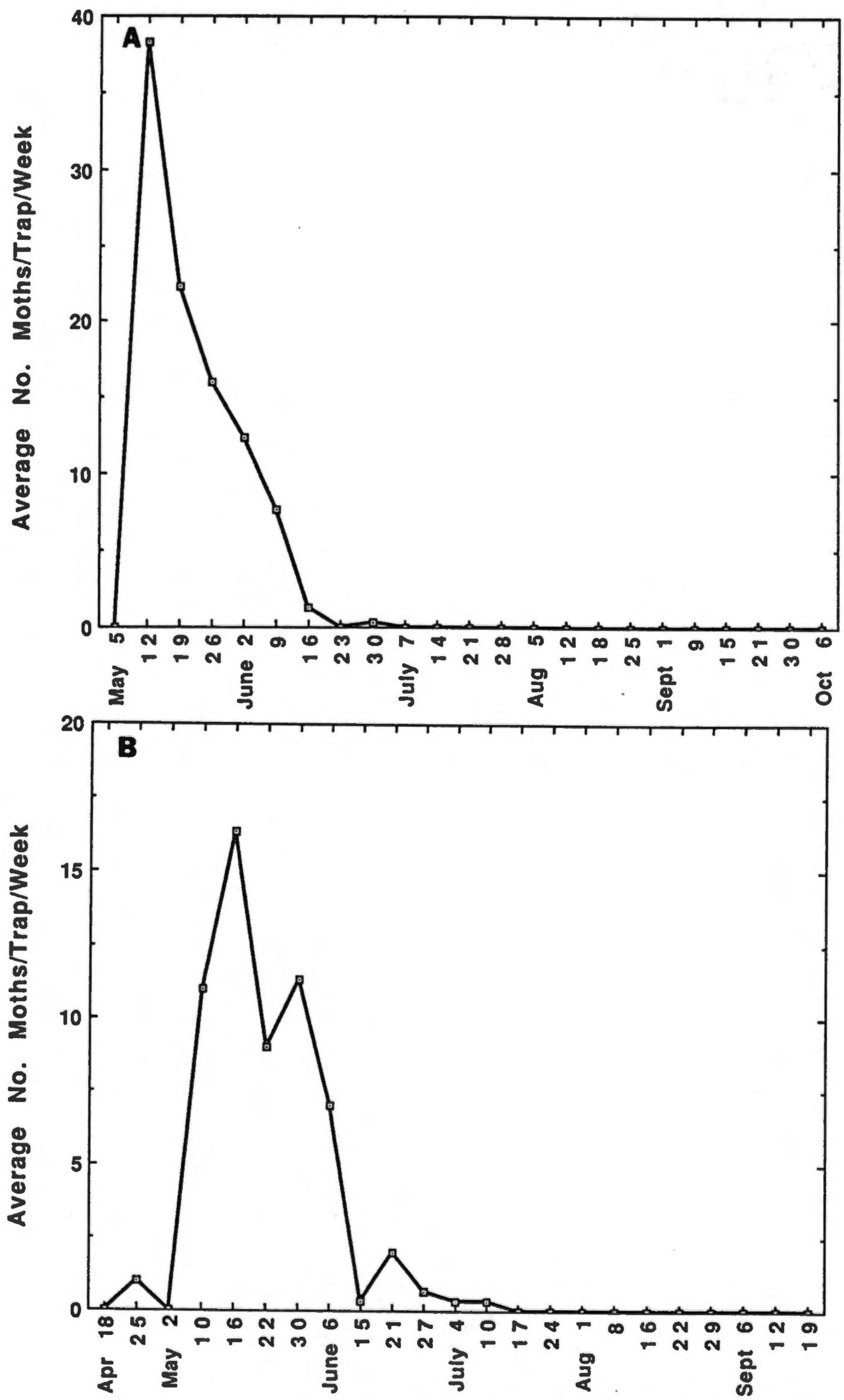

Figure 6. Seasonal incidence of Podosesia syringae in the forest habitat in eastern Tennessee during (A) 1987 and (B) 1988.

May. Twice as many lilac borers were collected in eastern and middle Tennessee in 1987 than 1988. The low numbers of lilac borers collected in 1988 may be the result of weather conditions (e.g. drought) in 1988 which could have an adverse effect on the condition of the tree and slow development of the borer.

Paranthrene simulans "palmii" was collected from early May until the middle of July (Figure 2) with peak adult activity occurring approximately the third week of May in 1987 and 1988 in all habitats (Figures 7-10). In 1987, ca. 10x more P. simulans "palmii" were collected than in 1988. Past research has indicated that this species emerges in greater numbers during even-numbered years (Engelhardt 1946). The results of this study, however, agree with those of Neal and Eichlin (1983) in Maryland and neighboring mid-Atlantic states and suggest that high numbers of P. simulans "palmii" occurred during an odd-numbered year. Engelhardt (1946) reported that P. simulans has a two-year life cycle and, as a result, emerges in greater numbers every other year. A second peak of adult activity was evident in each habitat and may indicate a second period of emergence of P. simulans "palmii" from an alternate host.

Synanthedon scitula was active from the beginning of May until the beginning of October in 1987 and 1988 in

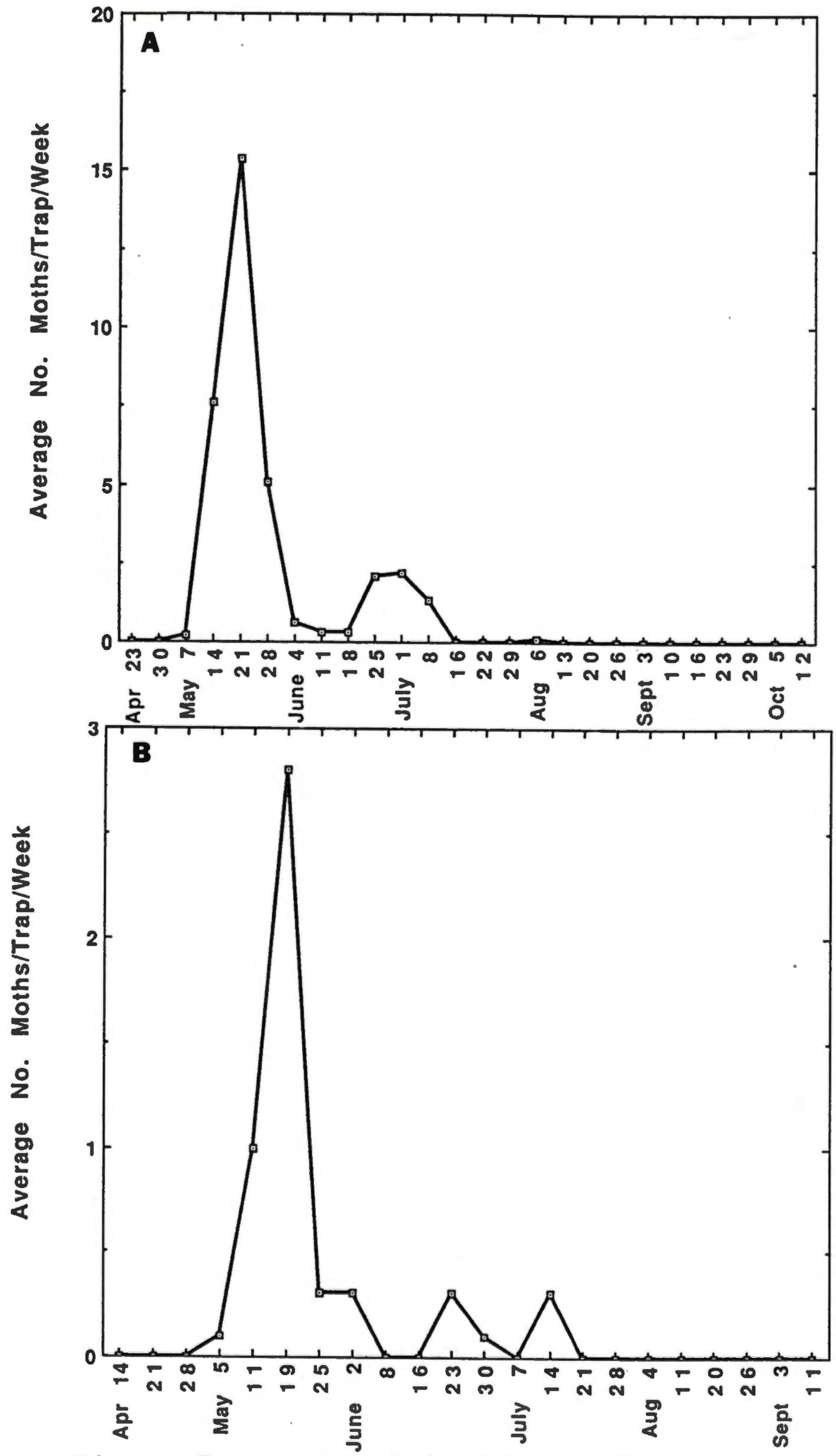

Figure 7. Seasonal incidence of *Paranthrene simulans* "palmii" in commercial nurseries in middle Tennessee during (A) 1987 and (B) 1988.

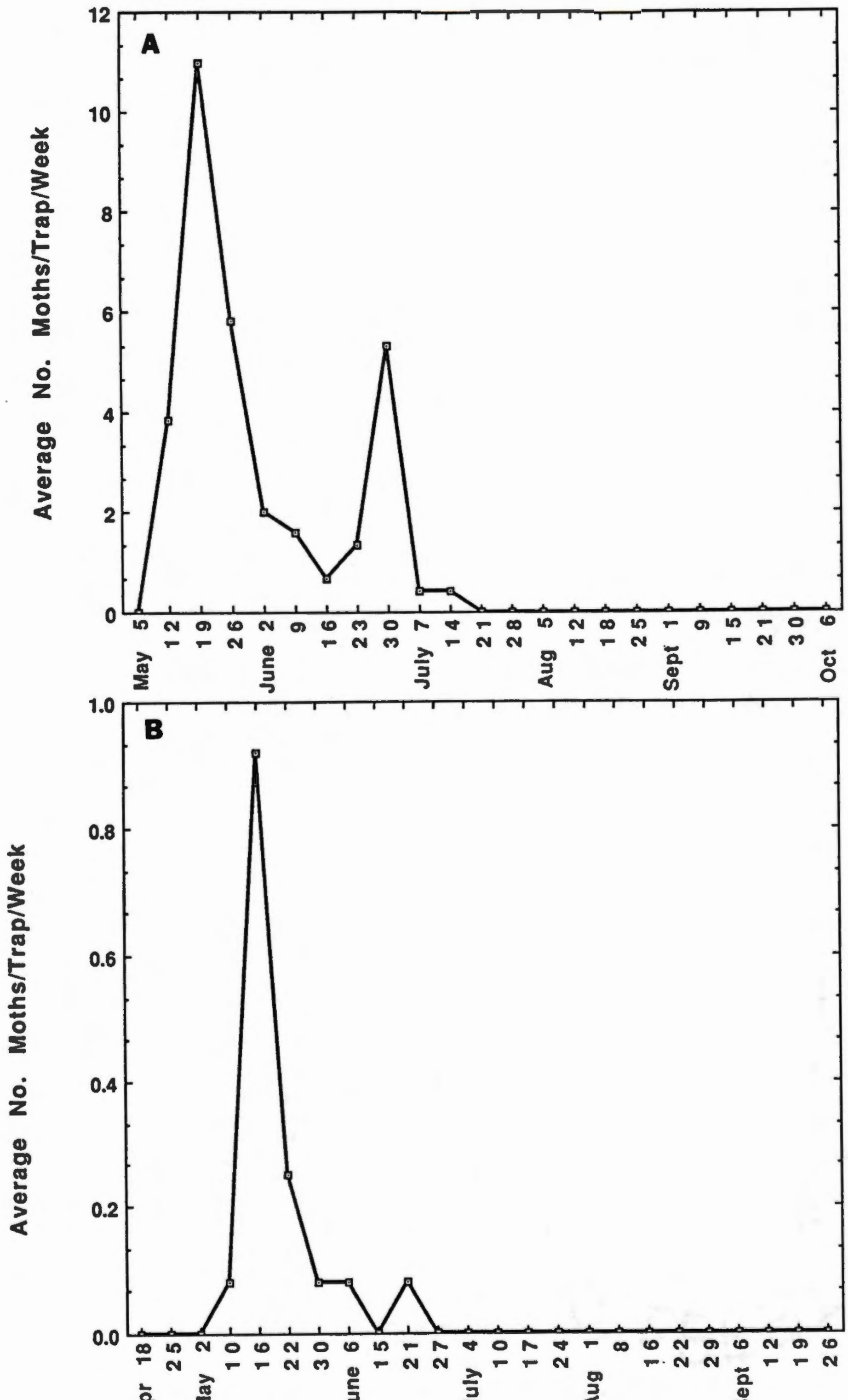

Figure 8. Seasonal incidence of Paranthrene simulans "palmii" in eastern Tennessee (combined for all habitats) during (A) 1987 and (B) 1988.

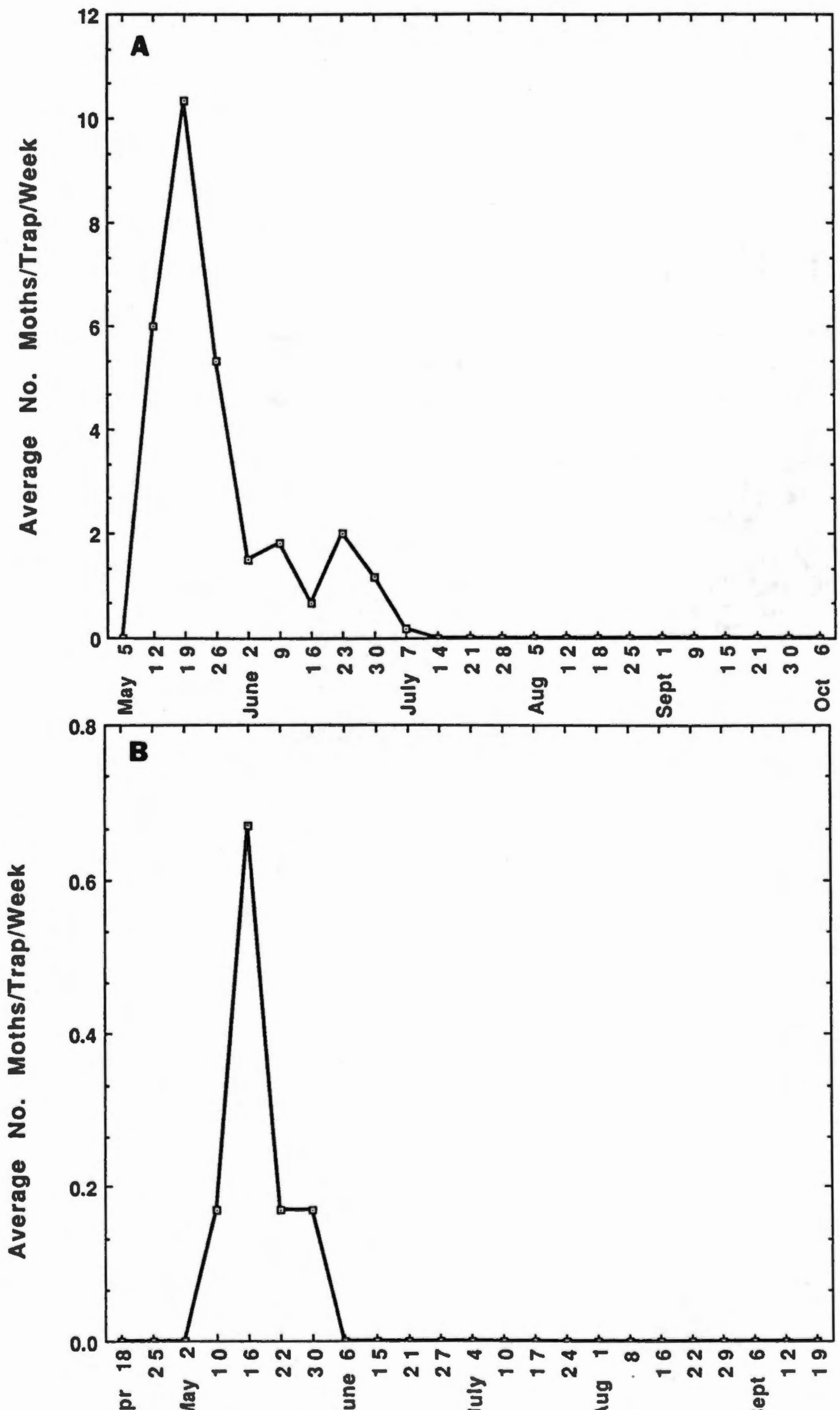

Figure 9. Seasonal incidence of Paranthrene simulans "palmii" in the urban habitat in eastern Tennessee during (A) 1987 and (B) 1988.

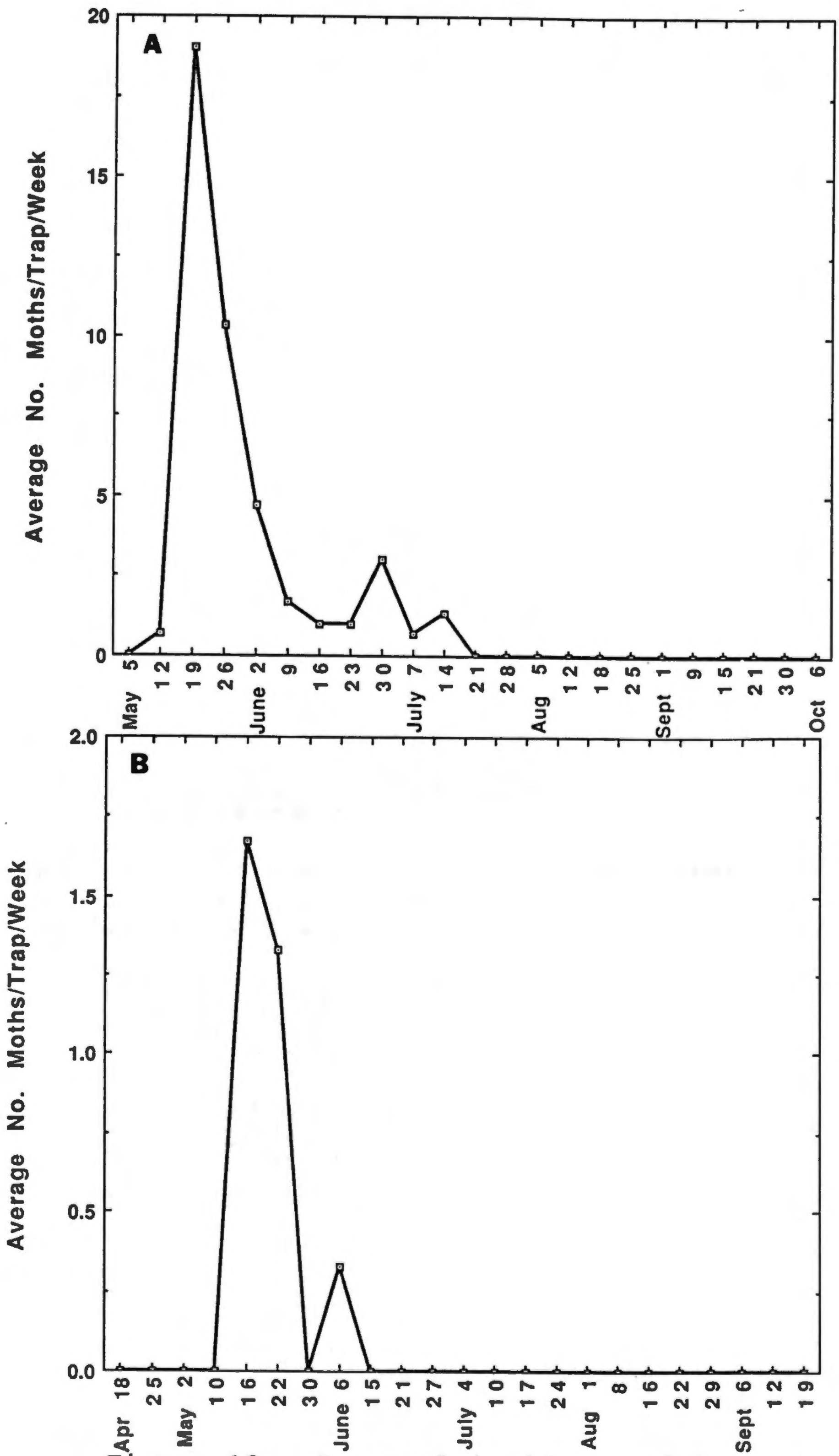

Figure 10. Seasonal incidence of Paranthrene simulans "palmii" in the forest habitat in eastern Tennessee during (A) 1987 and (B) 1988.

eastern and middle Tennessee (Figure 2). In the commercial nursery and urban habitats, S. scitula exhibited a bimodal period of emergence during both years with the first peak occurring in mid-May and the second in early August (Figures 11-13). These data agree with the research of Potter and Timmons (1983a) in Kentucky. They suggested that the second peak of adult flight activity of S. scitula consists primarily of borers emerging from alternate hosts and indicated the importance of apple as an alternate host for S. scitula. The existence of two peaks of adult activity of S. scitula has important control implications and supports the use of two properly timed chemical applications for control of this borer. Borers are only vulnerable to chemical application from the time of eclosion to penetration of the bark, therefore, treatment must beed at the proper time for successful pest control.

Adult Synanthedon rhododendri were collected from the end of May until the beginning of September (Figure 2). This species generally exhibited one peak of adult activity in early May to mid-June in the commercial nursery and urban habitats in 1987 and 1988 (Figures 14 and 15). The emergence of S. rhododendri may be extended in the forest habitat as a result of cooler temperatures and longer developmental times. The extended period of emergence in the forest may also be the result of multiple hosts (i.e.,

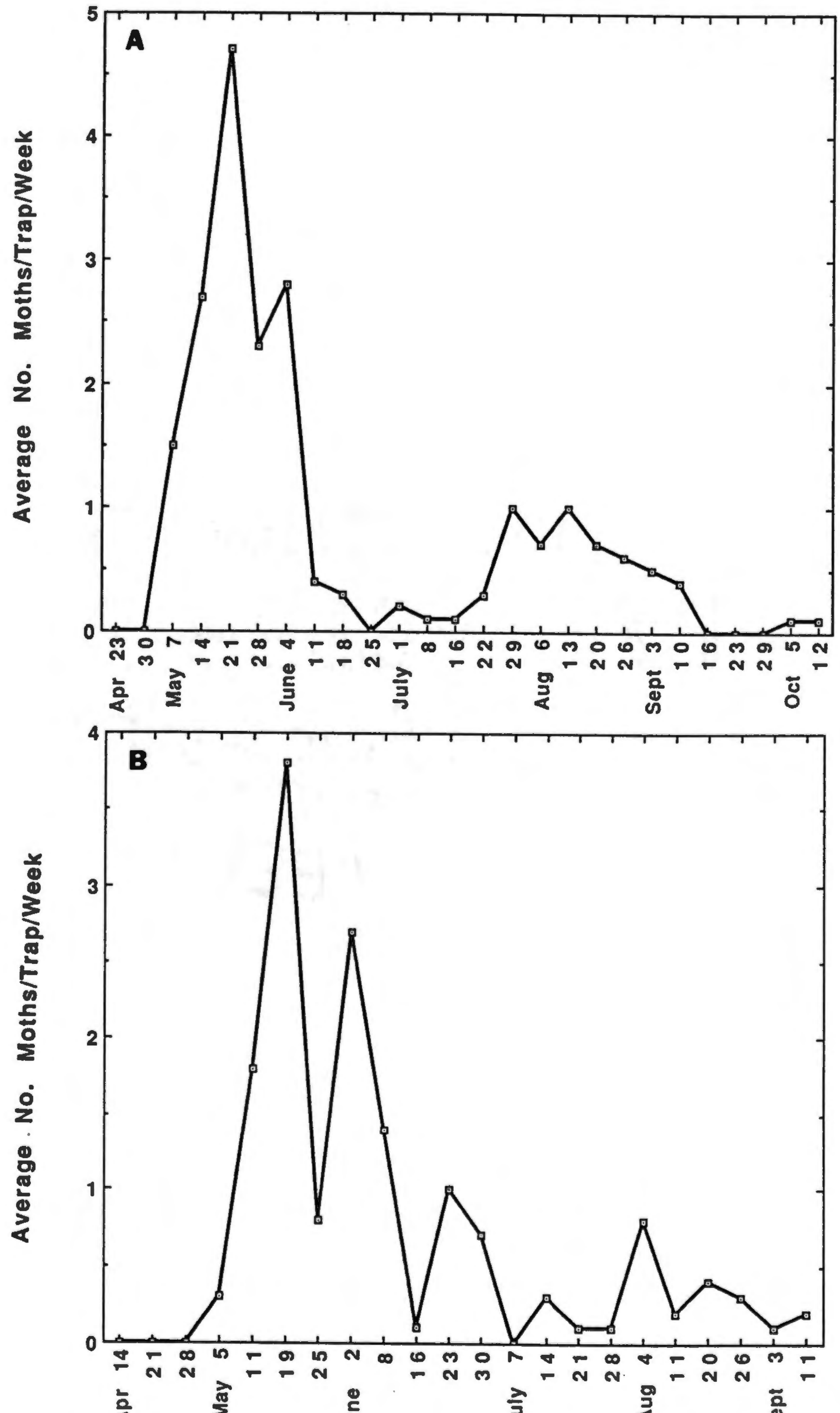

Figure 11. Seasonal incidence of <u>Synanthedon scitula</u> in commercial nurseries in middle Tennessee during (A) 1987 and (B) 1988.

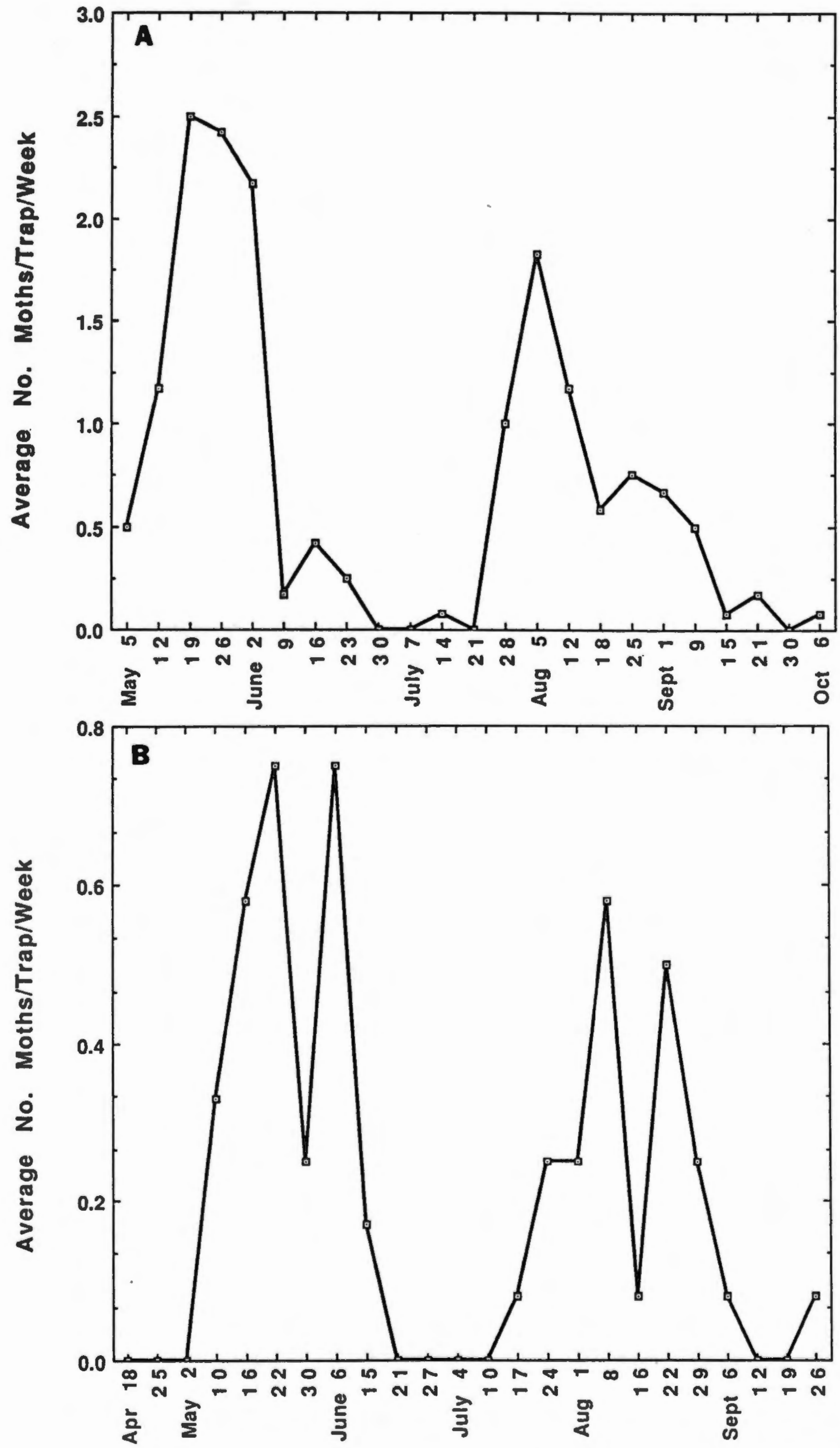

Figure 12. Seasonal incidence of <u>Synanthedon scitula</u> in eastern Tennessee (combined for all habitats) during (A) 1987 and (B) 1988.

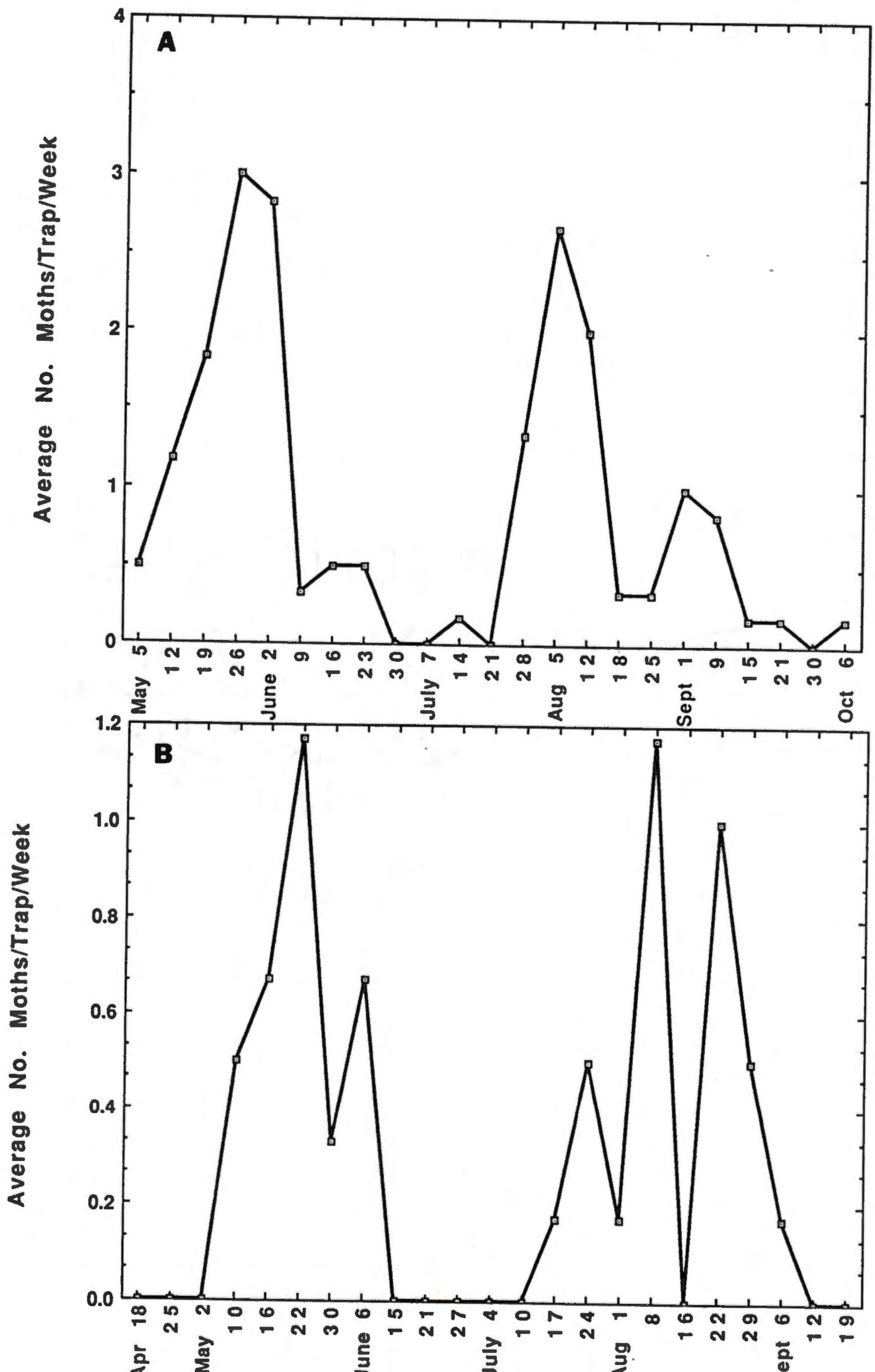

Figure 13. Seasonal incidence of Synanthedon scitula in the urban habitat in eastern Tennessee during (A) 1987 and (B) 1988.

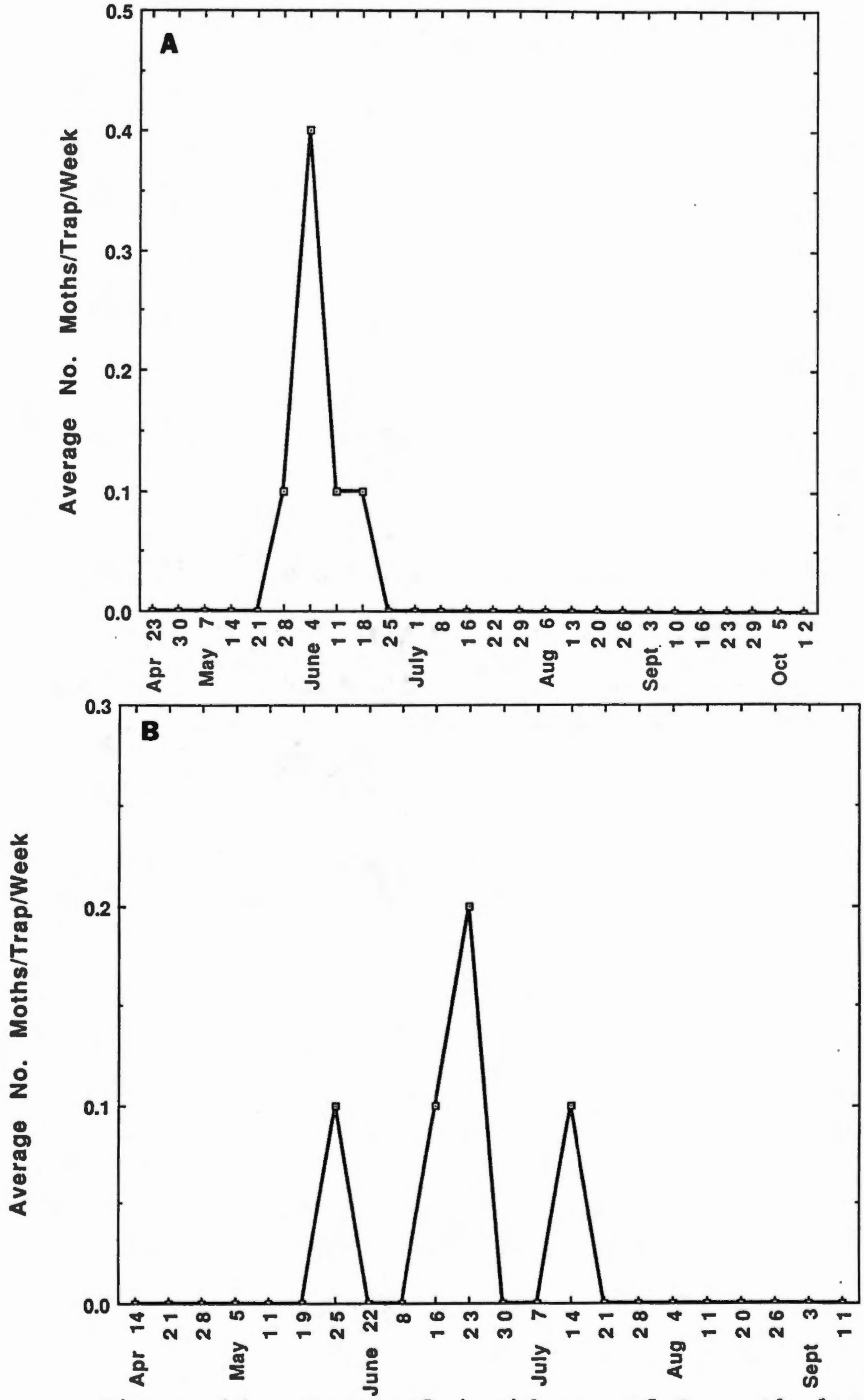

Figure 14. Seasonal incidence of Synanthedon rhododendri in commercial nurseries in middle Tennessee during (A) 1987 and (B) 1988.

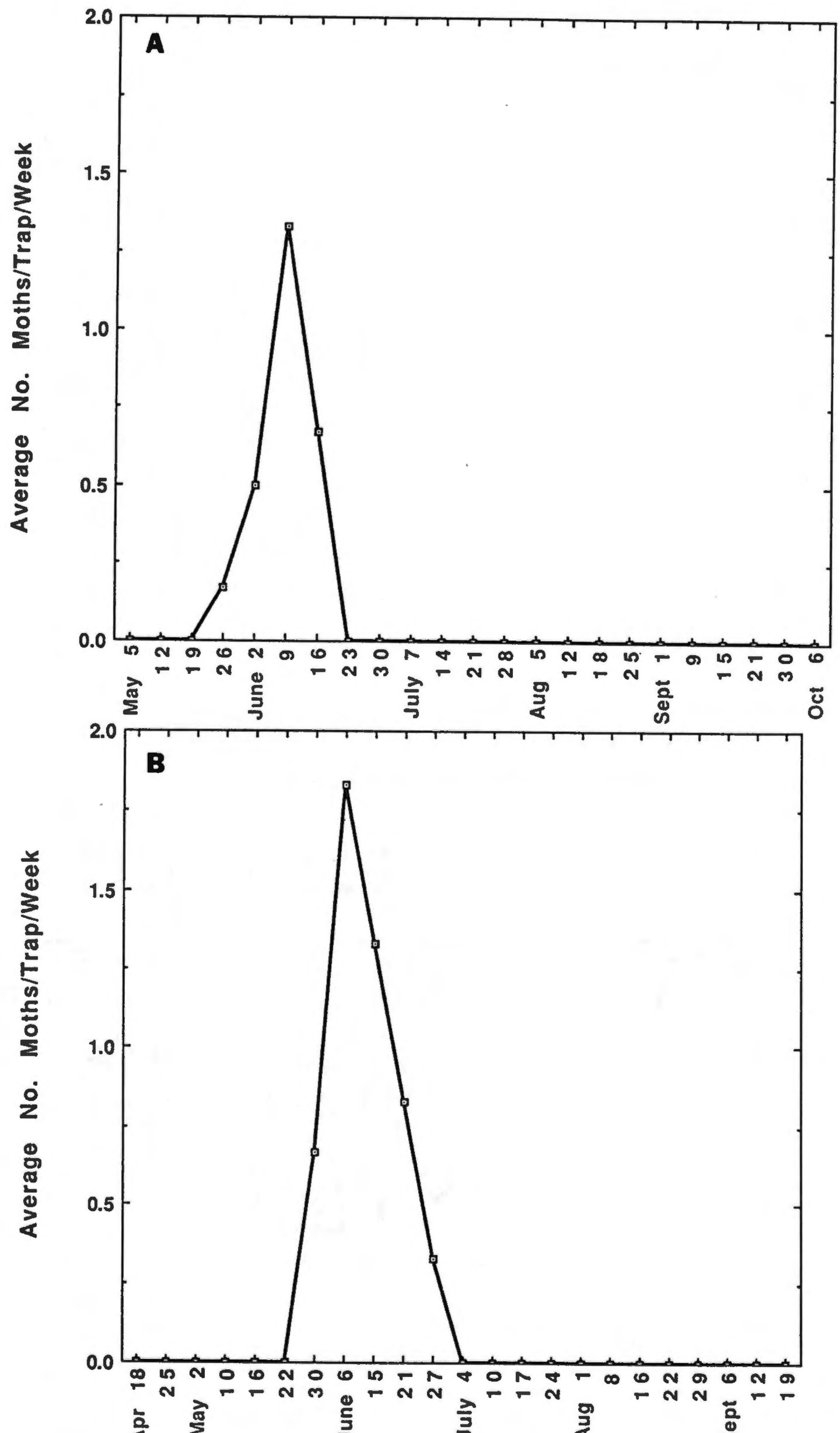

Figure 15. Seasonal incidence of Synanthedon rhododendri in the urban habitat in eastern Tennessee during (A) 1987 and (B) 1988.

rhododendrons and mountain laurels) for this borer. Emergence in the forest habitat and in eastern Tennessee occurred from the end of May to the beginning of September (Figures 16 and 17).

Synanthedon exitiosa exhibited flight activity from late May through mid-September (Figure 2). Peak activity of *S. exitiosa* occurred at the end of August in eastern and middle Tennessee (Figures 18-20).

Synanthedon fatifera was found in the forest habitat in eastern Tennessee from the end of June until mid-August (Figure 2). This borer species was captured in low numbers and only in the forest habitat. Adult activity peaked during mid-July to mid-August (Figure 21).

Synanthedon acerni was trapped in low numbers in the urban habitat in eastern Tennessee in 1987 on 10 May and 22 May and in middle Tennessee on 11 May 1988. *Synanthedon decipiens* was also collected in low numbers. This borer species was collected from 19 May to 2 June in 1987 and from 14 May to 21 May in 1988 in the commercial nurseries in middle Tennessee.

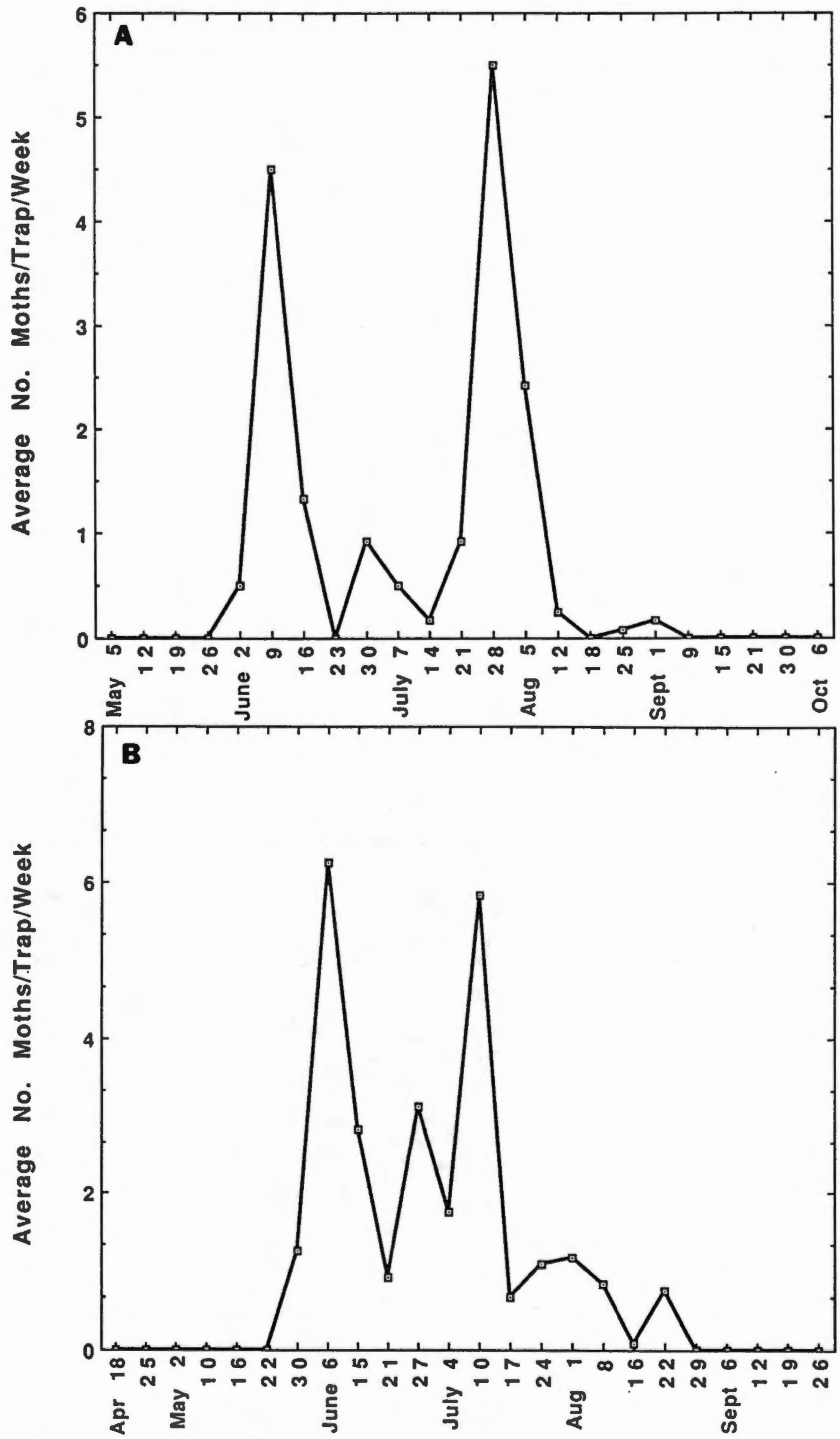

Figure 16. Seasonal incidence of Synanthedon rhododendri in eastern Tennessee (combined for all habitats) during (A) 1987 and (B) 1988.

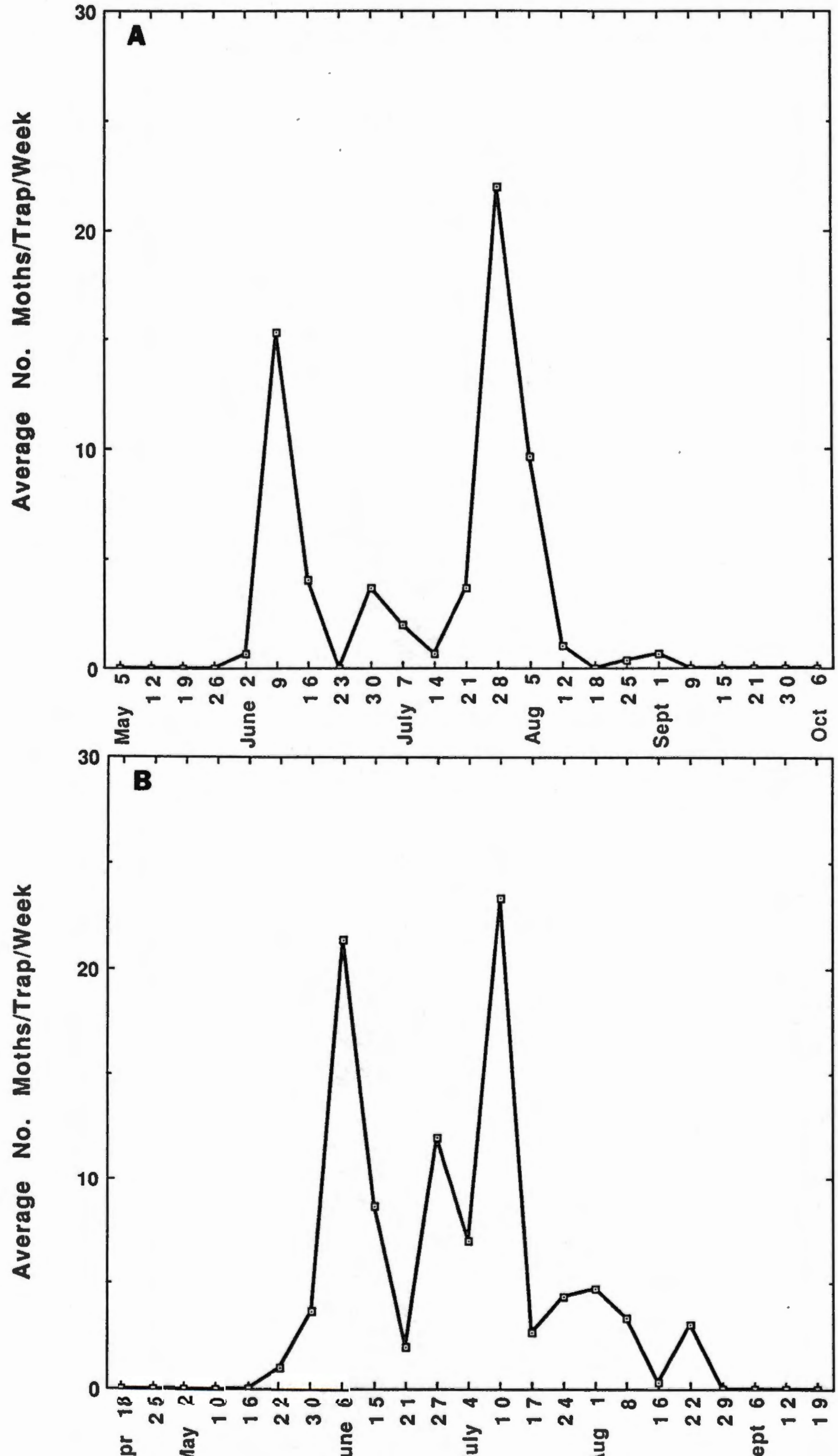

Figure 17. Seasonal incidence of _Synanthedon rhododendri_ in the forest habitat in eastern Tennessee during (A) 1987 and (B) 1988.

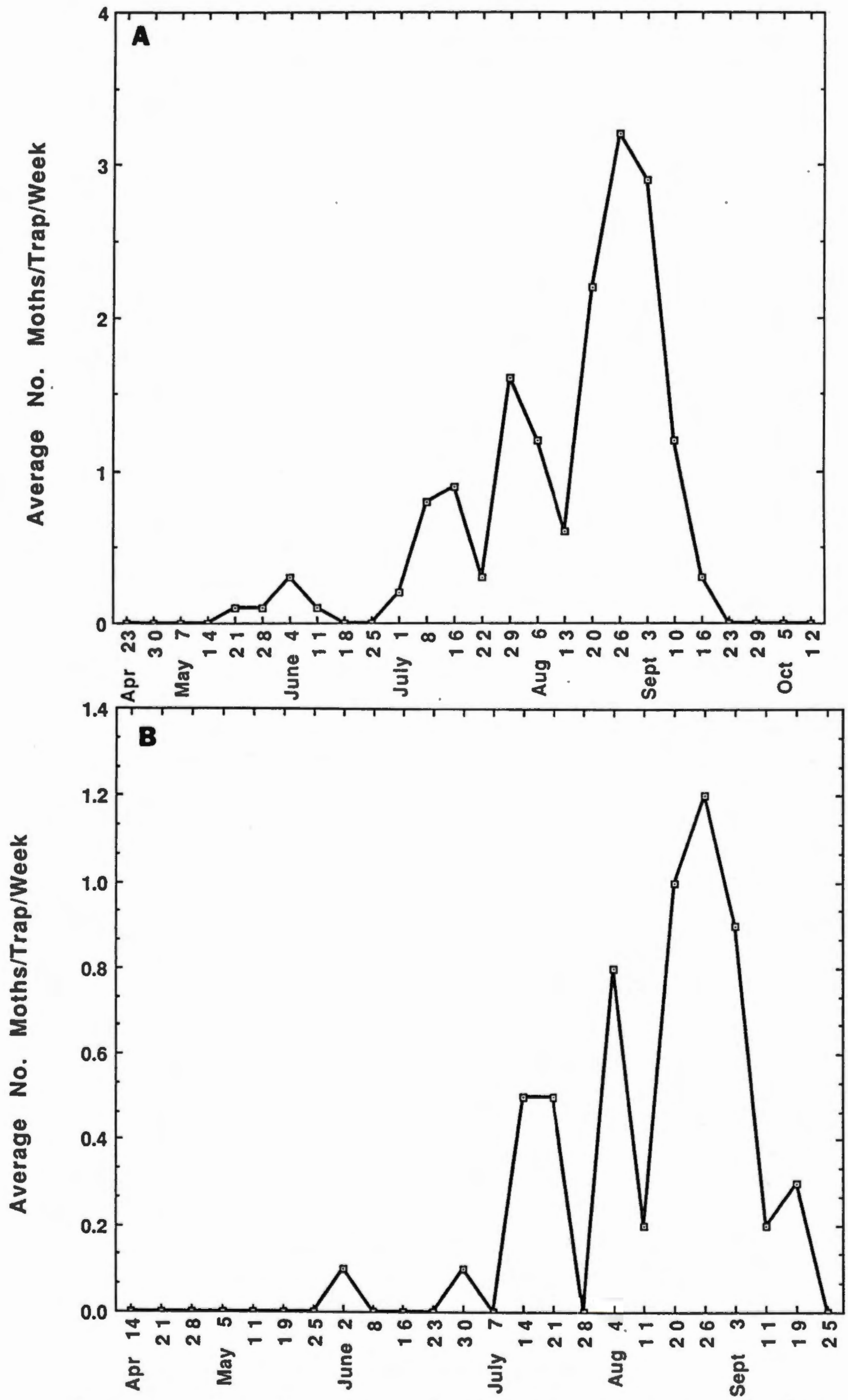

Figure 18. Seasonal incidence of Synanthedon exitiosa in commercial nurseries in middle Tennessee during (A) 1987 and (B) 1988.

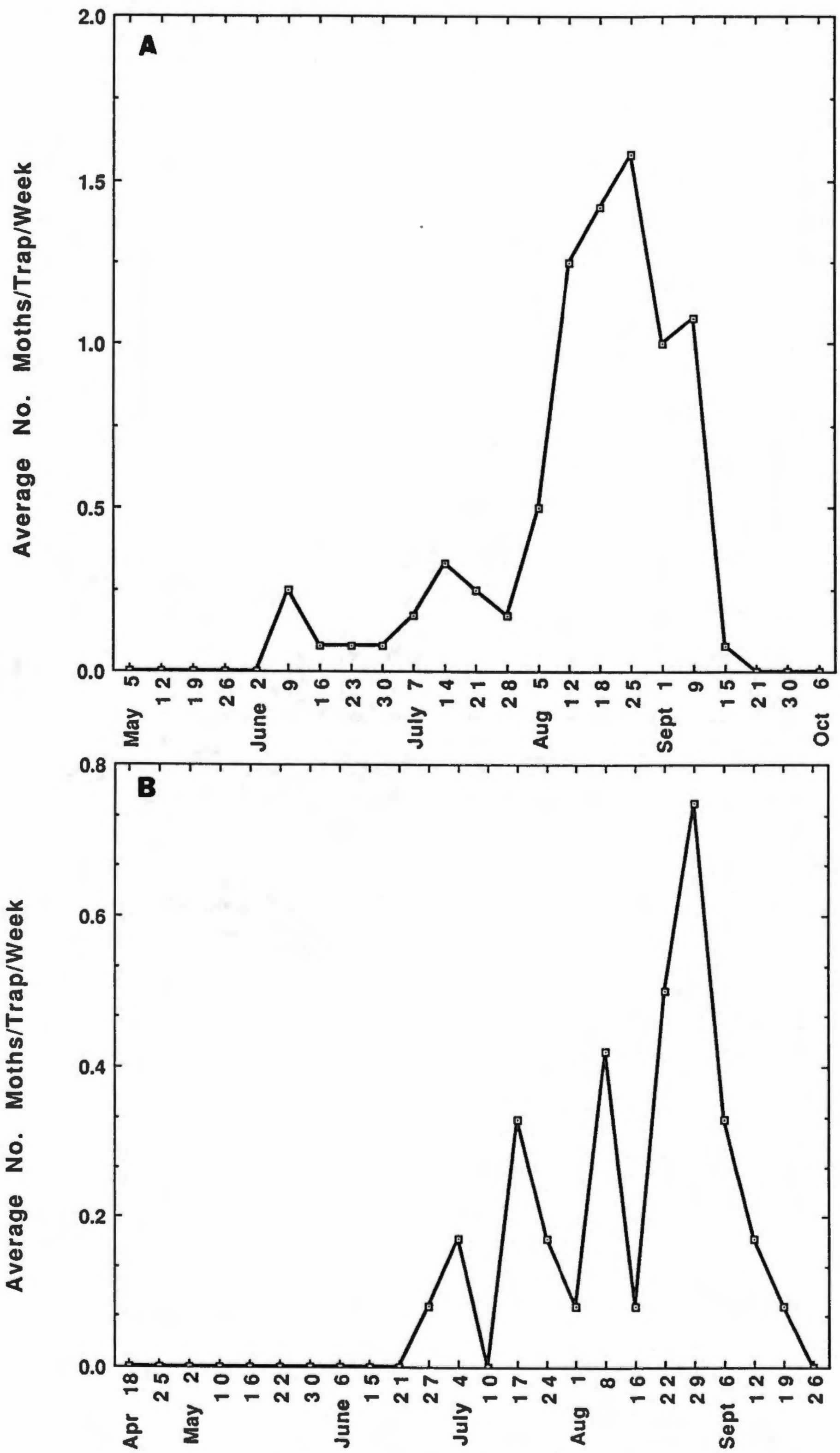

Figure 19. Seasonal incidence of Synanthedon exitiosa in eastern Tennessee (combined for all habitats) during (A) 1987 and (B) 1988.

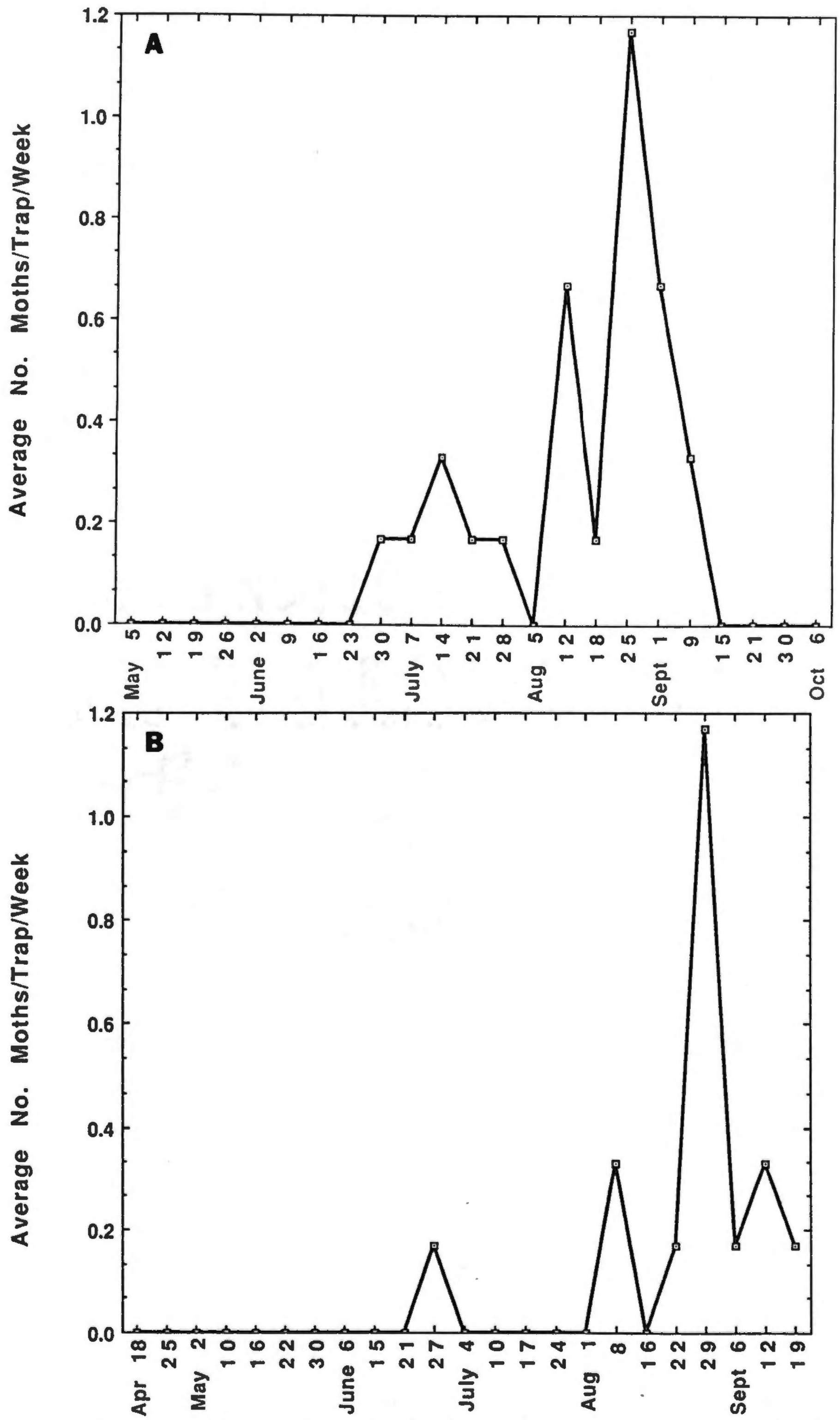

Figure 20. Seasonal incidence of Synanthedon exitiosa in the urban habitat in eastern Tennessee during (A) 1987 and (B) 1988.

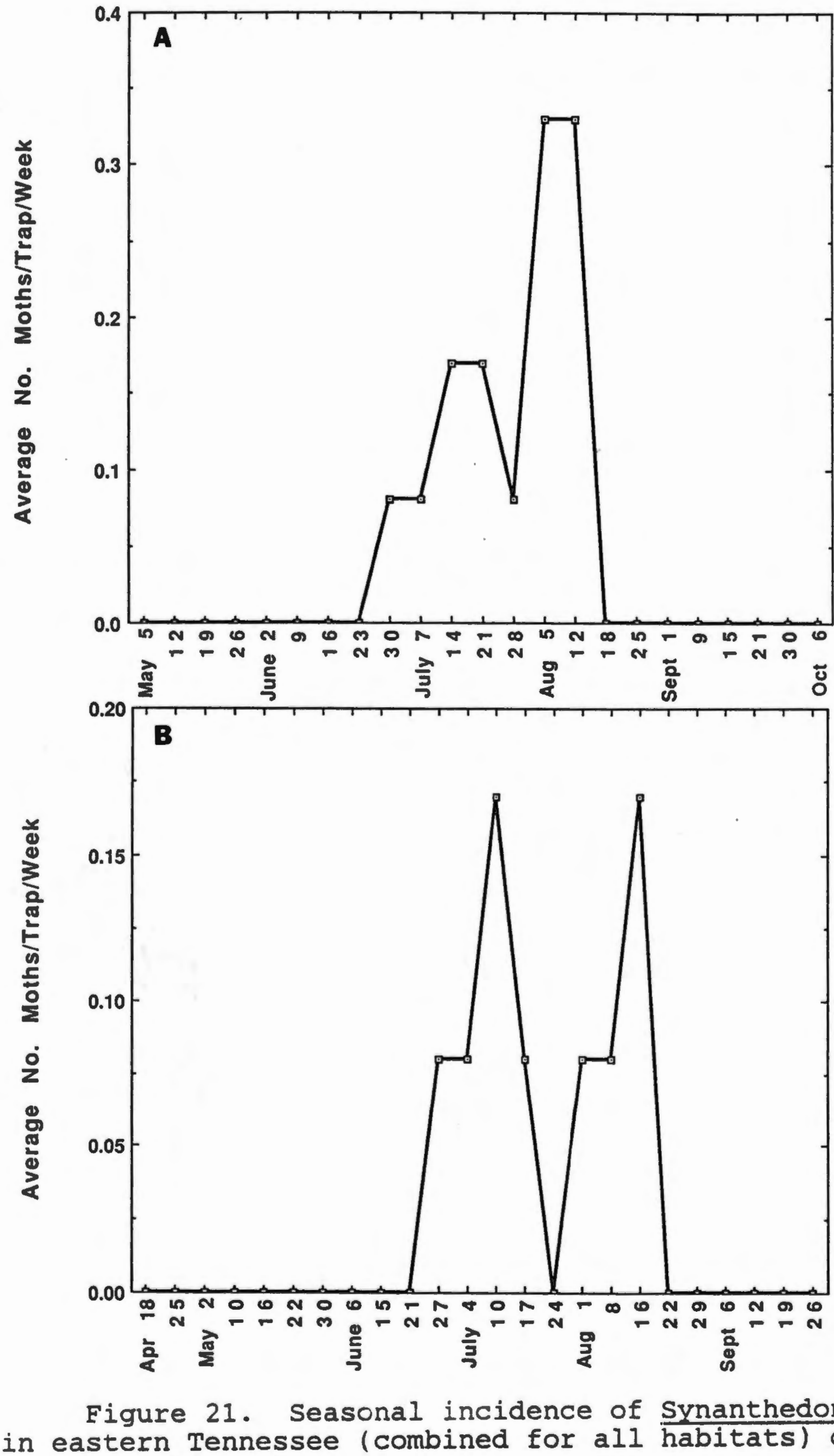

Figure 21. Seasonal incidence of Synanthedon fatifera in eastern Tennessee (combined for all habitats) during (A) 1987 and (B) 1988.

CHAPTER III

INFESTATION LEVELS OF DOGWOOD BORER LARVAE ON DOGWOOD TREES IN SELECTED HABITATS (COMMERCIAL NURSERY, URBAN, AND FOREST) IN TENNESSEE

i. INTRODUCTION

The flowering dogwood, *Cornus florida* L., an ornamental with widespread use in the eastern United States, is grown in large numbers in commercial nurseries for sale in Tennessee and other states. The flowering dogwood is the most popular tree sold by Tennessee nurserymen (Williams et al. 1985), accounting for 16% of the total ornamental plant production. Gross sales of dogwood grown in Tennessee is estimated to be 24 million dollars annually (Day, personal communication).

The dogwood borer, *Synanthedon scitula* (Harris), is the most destructive insect pest of dogwood in Tennessee (Williams et al. 1985). Economic losses incurred by nurserymen due to dogwood borer injury can exceed $2,000 per block of dogwoods. This estimate is based on 6% infestation of a 3,000 tree block ($11.00/tree). In addition, the cost of treatment for the control of dogwood borer in nursery blocks can often be expensive. The impact of dogwood borers on trees grown as an ornamental in the urban landscape and the resultant monetary losses to homeowners are difficult to estimate (Nielsen 1978a). The use of pesticide sprays is often the primary approach to pest control in the urban landscape and is often a very expensive measure of control (Smith and Raupp 1986).

Little information is available on infestation levels of dogwood borer on dogwood in commercial nurseries, urban landscapes, and forest habitats. Previous researchers have reported low infestation of dogwood borer on native dogwoods in forested areas (Pless and Stanley 1967, Underhill 1935). Most of the infestations in urban landscapes and nurseries are associated with bark injuries to young trees and pruning scars or cankers in older (>20 cm diameter) trees (Potter and Timmons 1981).

In 1987, a two-year study was initiated to determine infestation levels of dogwood borer on dogwood in nursery blocks, urban landscapes, and forest habitats in Tennessee. The distribution of dogwood borer infestations in commercial nursery dogwood blocks was also investigated.

ii. MATERIALS AND METHODS

INFESTATION LEVELS

Levels of infestation of dogwood borer larvae on dogwood trees in selected habitats (commercial nursery, urban, and forest) were measured in 1987 and 1988. Levels of infestation in the nursery habitat were determined by examining each individual tree in 13 blocks of dogwood (range=275 to 7624 trees/block) in commercial nurseries in middle Tennessee for borer incidence. Each block was characterized for age of trees, level of weediness, and pesticide applications to the field (Appendix A). Tree age was determined by the number of years the tree had been in the field. Level of weediness was determined by rating each field by visual examination for the absence or degree of presence of weeds (none-low=<10%, few=10-30%, many=>30%). To determine infestation levels in urban and forest habitats, dogwood trees (ca. 75 at each site) were randomly selected in Knox County (urban-2 sites) and Blount County (forest-13 sites) in eastern Tennessee and examined for borer infestation.

To determine borer incidence, the trunk and base of each individual tree in each habitat were examined for the presence of potential larval entry sites or frass, fine particulate boring dust mixed with excrement, that is pushed out of the tree as the borer excavates a tunnel. Infestation was confirmed by removing a layer of bark to reveal the dogwood borer. Infested trees were then flagged with colored ribbon for easy identification.

Trunk diameter (30 cm above ground level) and tree height were measured for each infested tree as well as for a random sample (ca. 50 trees at each site) of non-infested trees. For each infested tree, the height of the infestation site above ground level and diameter of the tree at the site of infestation were also measured.

DISTRIBUTION

To evaluate distribution of dogwood borer larvae in commercial nursery blocks of dogwood, each block (n=13) was mapped to relate distribution of infested trees with those determined to be non-infested. The presence of infested, non-infested, and standing dead trees in each row was indicated on the map. This information was then examined to characterize the distribution of dogwood borer in the field.

iii. RESULTS AND DISCUSSION

INFESTATION LEVELS

Commercial nursery. The average percent infestation in the commercial nursery was 6.56 ± 2.31%/block (n=13 blocks, $\bar{x}$=1,770 trees/block). Percent infestation of dogwood trees in this habitat varied widely and ranged from 0.14 to 24.89%/block (Table 4). Six blocks (46%) had infestation levels ranging from 1.04 to 11.14% and five (38.5%) of the blocks had infestation levels less than 1%. Although overall infestation level was low, infestation levels in two of the blocks were greater than 21%. Grant (unpubl. data) found infestation levels in some dogwood blocks in Tennessee to be greater than 40%. The variability in

Table 4. Classification of percent infestation levels of dogwood nursery blocks (n=13) in commercial nurseries in middle Tennessee

Infestation Level (%)	n	Range
0	0	0
<01.00	5	0.14- 0.98
1.01-05.00	2	1.04- 2.50
5.01-10.00	3	5.13- 8.97
10.01-15.00	1	11.14
15.01-20.00	0	0
20.01-25.00	2	21.95-24.89
>25.00	0	0

infestation levels in the nursery blocks may be the result of pest management practices and the number of years that the dogwood trees have been in the field.

The average height and diameter of infested trees in the commercial nursery were slightly greater than those of non-infested trees (Table 5). The height of the infestation site above ground level averaged ca. 12cm. Potter and Timmons (1981) reported that almost all of the infestation sites they found on younger trees (<15cm diameter) were on the main trunk and within 50cm of the ground. Previous researchers reported that dogwood borer infestations in younger trees were mostly located in the crown of the tree. In this study, 98.37% (n=724) of the infestation sites on dogwood trees in the commercial nurseries examined were within 50cm of the ground. These results agree with those of Potter and Timmons (1981).

Tree age influenced the level of infestation of dogwood borer larvae on dogwood trees. Average percent infestation in the commercial nurseries was highest (ca. 12%) in those blocks with 3-4 year old trees (Table 6). Trees that had been in the field for less than two years had the lowest infestation levels (ca. 0.2%). These results suggest that establishment of dogwood borer in commercial nursery blocks requires at least one growing season to allow time for larval entry sites to develop, adults to lay eggs and for larvae to penetrate the bark

Table 5. Mean ($\pm$SEM) height and diameter[1] of infested and non-infested trees and mean ($\pm$SEM) height and diameter of the location of the infestation site in the commercial nursery habitat

	Number of Trees (n)	$\bar{x}$ Tree Height (cm)	$\bar{x}$ Tree Diameter[1] (cm)	$\bar{x}$ Height of Infestation (cm)	$\bar{x}$ Diameter at Infestation Site (cm)
Infested	736	127.55$\pm$7.18	1.94$\pm$0.17	12.04$\pm$3.23	2.67$\pm$0.26
Non-infested	787	120.97$\pm$6.40	1.69$\pm$0.13	-	-

[1] Tree diameter was measured at 30cm above ground level.

Table 6. Influence of tree[1] age on selected infestation characteristics in the commercial nursery

Tree Age[1]	n	$\bar{x}$ Tree Diameter[2] (mm)	$\bar{x}$ Infestation Level (%)	$\bar{x}$ Height of Infestation (cm)	$\bar{x}$ Diameter at Infestation Site (mm)
<2 years	1	12.85±0.00	0.16±0.00	0.00±0.00	15.10± 0.00
2 years	4	17.80±1.21	0.58±0.18	15.14±8.49	24.87± 3.12
3-4 years	6	18.80±2.00	11.88±3.90	14.37±3.81	25.42± 2.17
>5 years	2	27.55±8.56	5.74±3.24	4.88±1.17	39.81±12.74

[1] Age was determined by the number of years the tree had been in the field.

[2] Tree diameter was measured at 30cm above ground level.

tissue. Trees that had been in the field for 5 years had lower infestation levels than 3-4 year old trees since blocks with older trees were usually abandoned blocks with large amounts of weeds and, therefore, similar to forest habitats.

Certain management practices also had an effect on the levels of percent infestation of dogwood borer in nursery blocks. Those blocks treated with insecticides (e.g., Dursban, Lindane) for control of borers and other insect pests had lower percent infestation levels than those that were not treated for insect pests (Table 7, Appendix B). Dogwood borers were found in all nursery blocks with average percent infestation ranging from 0.14 to 11.14% in those blocks treated with insecticides and from 1.04 to 24.89% in the non-treated blocks. One of the treated blocks had an infestation level of ca. 11%. This information is important from a managerial standpoint because high infestation levels in treated blocks could be the result of improper timing of direct control. Dogwood borers are vulnerable to chemical insecticides only from the time of eclosion to penetration of the bark; therefore, proper timing of control methods is important.

The level of weediness within a dogwood block also influenced the level of infestation of dogwood by dogwood borer. Nursery blocks with low numbers of weeds also had low levels of borer infestation (Table 8). Those blocks

Table 7. Influence of insecticide treatment on infestation of dogwoods by dogwood borer in commercial nurseries in middle Tennessee

Treatment[1]	n	Mean($\pm$SEM) Infestation Level/ Block (%)
Treated	9	3.15 ± 1.29
Non-treated	4	14.21 ± 5.59

[1] Treatment indicates those blocks treated with insecticides (Dursban, Lindane) for control of dogwood borer and other insect pests.

Table 8. Influence of weeds on infestation of dogwoods by dogwood borer in commercial nurseries in middle Tennessee

Weed Rating[1]	n	Mean (±SEM) Infestation Level/Block (%)	Range
None-low	4	0.45±0.2	0.14- 0.98
Few	4	6.11±2.1	1.04-11.14
Many	5	11.80±5.0	0.71-24.89

[1] Weed rating was determined by rating each field by visual examination for the absence or degree of presence of weeds (none-low=<10%, few=10-30%, many=>30%).

where weeds were classified as "many" had twice the infestation level of those blocks where weeds were classified as "few". Few to no weeds in a field could reflect management practices and may suggest that both herbicides and insecticides were applied to the block.

Urban. The average percent infestation of dogwood trees by dogwood borers in the urban habitat in eastern Tennessee was 60.08% (n=243). This high infestation level in the urban habitat is primarily due to adverse environmental conditions which can weaken the tree and increase susceptibility to borer infestation. Dogwood trees are particularly susceptible to borer infestation when planted in full sun in the urban landscape (Potter and Timmons 1981). Also, dogwood trees planted in the urban landscape are more likely to become mechanically injured (e.g., damaged by a lawnmower or weed-eater) providing entry sites for borer infestation. Diameter (at 30cm above ground level) of infested trees was similar to that of non-infested trees, ranging from 4.0cm to 39.0cm for infested trees and from 3.0cm to 41.0cm for non-infested trees (Table 9).

Infestation sites on dogwoods in the urban habitat were located higher on the tree than those in the commercial nursery (Table 9). The average height of the infestation site above ground level in the urban habitat

Table 9. Mean (±SEM) diameter[1] and mean (±SEM) height and diameter of the location of the infestation site for infested and non-infested trees in the nursery, urban landscape, and forest habitats

Habitat	n		$\bar{x}$ Tree Diameter[1] (cm)		$\bar{x}$ Height of Infestation (cm)	$\bar{x}$ Diameter at Infestation Site (cm)
	Infested	Non-infested	Infested	Non-infested		
Nursery	736	787	1.94±0.18	1.69±1.27	12.04± 3.23	2.67±0.26
Urban	146	97	16.47±0.75	16.35±0.90	39.38± 2.34	16.41±0.61
Forest	9	859	5.26±1.92	5.92±0.39	96.5±17.78	5.21±1.66

[1] Tree diameter was measured at 30cm above ground level.

was ca. 39cm, ranging from 0cm to 127cm, while the average height of the infestation site in the commercial nursery was only 12cm, ranging from 0cm to 65cm. Most infestation sites in older trees (>20cm diameter) are higher in the limb crotches or major branches and usually associated with pruning scars, cankers, or areas of cracked and raised bark (Potter and Timmons 1981). The results in this study indicated similar trends with infestation sites higher on the older trees examined in the urban landscape than on the younger trees examined in the commercial nursery. Average diameter of the tree at the site of infestation in the urban habitat was ca. 16cm, ranging from 3.0cm to 40.0cm. Infestation sites were located higher on the tree in the urban landscape than on the younger trees in the commercial nursery.

<u>Forest.</u> Fewer borer-infested trees were found in the forest habitat than in the urban or nursery habitats (Table 9). Borer infestation averaged 1.04% in the forest habitat. The low infestation level in the forest may primarily be attributed to the natural condition of the dogwood tree as a component of the forest understory. Native dogwoods are partially shaded in the forest and are not subject to mechanical injuries (e.g., damage caused by lawn mowers) that would increase the susceptibility of the tree to borer infestation by providing an entrance into the inner bark of

the tree.

Average diameter (at 30cm above ground level) of non-infested trees was only slightly greater than that of infested trees in the forest (Table 9). Diameter of non-infested trees ranged from 0.64cm to 27.94cm and diameter of infested trees ranged from 1.9cm to 10.8cm. The variability among diameters of infested and non-infested trees in the forest is due to the broad range of tree ages in the forest.

The height of the infestation site averaged ca. 97cm, ranging from 33.0 to 139.7cm, above ground level in the forest habitat (Table 9). The height of the infestation site in the forest habitat was much greater than the height of the infestation site in the commercial nursery or urban habitats (Table 9). Infestation sites may be higher on trees in the forest than in other habitats because an extensive underbrush may prevent adult moths from ovipositing on lower areas of the trunk of the tree. Many of the trees in the forest habitat are often covered with moss which may also prevent oviposition on the tree.

DISTRIBUTION

The distribution of dogwood borer infestation on dogwood trees in the commercial nursery blocks varied among blocks but, overall, exhibited a random distribution. Blocks with high levels of infestation often had areas in the field where borer infestation was clumped. Those blocks, however, with low infestation levels did not exhibit clumped distribution of infested trees. The presence of standing dead trees or the absence of trees previously removed from the block had no effect on the distribution of dogwood borer in the field. These data must be further analyzed to accurately determine the spatial distribution of dogwood borer infestations in commercial nursery blocks.

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APPENDICES

APPENDIX A

CHARACTERISTICS OF BLOCKS

(SEASONAL INCIDENCE STUDY)

CHARACTERISTICS OF BLOCKS

(SEASONAL INCIDENCE STUDY)

Note: Age of trees was determined by the number of years the tree had been in the field.

Block A:

County: Warren
Plant: Dogwood
Variety: Cherokee Chief
Number of trees: 50
Age of trees: 10-12 years (budded seedlings)
Chemical pesticide treatment: Information not available

Block B:

County: Warren
Plant: Dogwood
Variety: World's Fair
Number of trees: ca. 500
Age of trees: 8 or more years
Chemical pesticide treatment: None for past 5 years; earlier-Lindane was used

Block C:

County: Warren
Plant: Dogwood
Variety: *Cornus florida*
Number of trees: 1341
Age of trees: 3-4 years (lined at 2 years)
Chemical pesticide treatment: Herbicide use only
Additional information: Extremely drought-stressed

Block D:

County: Warren
Plant: Dogwood
Variety: Mixed
Number of trees: 1197
Age of trees: 4-5 years (lined at 2 years)
Chemical pesticide treatment: Herbicide use only

Block E:

County: Warren
Plant: Apple
Variety: Mixed but included Radiant, Daugo, Snowdrift, Flame, Arkansas Black varieties of flowering crab
Number of trees: ca. 1000
Age of trees: 2 years (budded seedlings)
Chemical pesticide treatment: Malathion, Benlate, Captan

Block F:

County: Blount
Plant: Dogwood
Variety: Mixed
Number of trees: ca. 100
Age of trees: 3-5 years (seeded and budded seedlings)
Chemical pesticide treatment: Dursban

APPENDIX B

CHARACTERISTICS OF DOGWOOD BLOCKS

(INFESTATION STUDY)

CHARACTERISTICS OF DOGWOOD BLOCKS

(INFESTATION STUDY)

Note: Age of trees was determined by the number of years the tree had been in the field. Level of weediness was determined by a visual examination of the absence or degree of presence of weeds in the field (none-low=<10%, few=10-30%, many=>30%).

Block 1:
- County: Warren
- Variety: Mixed
- Number of trees: 604
- Age of trees: 2 years (budded seedlings)
- Chemical pesticide treatment: Dursban and herbicides
- Level of weediness: None-low

Block 2:
- County: Warren
- Variety: *Cornus florida*
- Number of trees: 1081
- Age of trees: 5 or more years (seeded)
- Chemical pesticide treatment: None
- Level of weediness: None-low

Block 3:
- County: Warren
- Variety: Mixed
- Number of trees: 640
- Age of trees: 1 year (budded seedlings)
- Chemical pesticide treatment: Dursban
- Level of weediness: None-low

Block 4:
- County: Warren
- Variety: Mixed
- Number of trees: 351
- Age of trees: 3 years
- Chemical pesticide treatment: Dursban
- Level of weediness: Few

Block 5:
- County: Warren
- Variety: Mixed
- Number of trees: 1341
- Age of trees: 3-4 years (budded seedlings)
- Chemical pesticide treatment: Herbicides
- Level of weediness: few

Block 6:

County: Warren
Variety: Mixed
Number of trees: 470
Age of trees: 3-4 years
Chemical pesticide treatment: None in past 2 years
Level of weediness: Many

Block 7:

County: Warren
Variety: Mixed
Number of trees: 275
Age of trees: 5 or more years
Chemical pesticide treatment: Dursban
Level of weediness: Many

Block 8:

County: Warren
Variety: Mixed
Number of trees: 3503
Age of trees: 2 years (seeded, budded seedlings)
Chemical pesticide treatment: Dursban and herbicides
Level of weediness: None-low

Block 9:

County: Warren
Variety: Mixed
Number of trees: 377
Age of trees: 3 years
Chemical pesticide treatment: Dursban
Level of weediness: Few

Block 10:

County: Warren
Variety: Mixed
Number of trees: 2247
Age of trees: 2 years (budded seedlings)
Chemical pesticide treatment: Dursban and herbicides
Level of weediness: None-low

Block 11:

County: Warren
Variety: Mixed
Number of trees: 7624
Age of trees: 3-4 years (budded seedlings)
Chemical pesticide treatment: Dursban and herbicides
Level of weediness: Few

<u>Block 12</u>:

County: Warren
Variety: Mixed
Number of trees: 4421
Age of trees: 2 years
Chemical pesticide treatment: Dursban
Level of weediness: Many

<u>Block 13</u>:

County: Warren
Variety: Mixed
Number of trees: 1197
Age of trees: 3-4 years
Chemical pesticide treatment: None in past 2 years
Level of weediness: Many

VITA

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