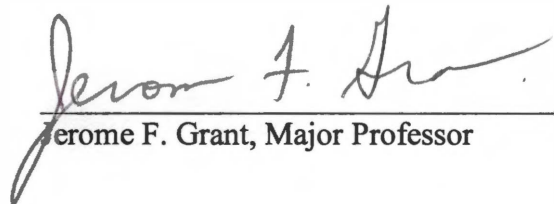


To the Graduate Council:

I am submitting herewith a thesis written by Kelly Reed Jackson entitled "Clearwing Moths (Lepidoptera: Sesiidae) in Southeastern Tennessee: Species Composition, Seasonality, and Elevational Influences." I have examined the final paper 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.



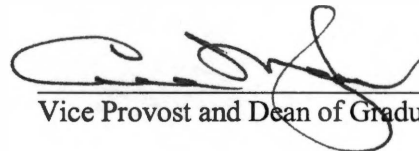
Jerome F. Grant, Major Professor

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CLEARWING MOTHS (LEPIDOPTERA: SESIIDAE)
IN SOUTHEASTERN TENNESSEE: SPECIES COMPOSITION, SEASONALITY,
AND ELEVATIONAL INFLUENCES

A Thesis
Presented for the
Master of Science
Degree
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Kelly Reed Jackson
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Thesis
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DEDICATION

This thesis is dedicated to my wife, Ashley Jackson, for her love, patience and understanding during these last several years. Her commitment and encouragement are a source of inspiration and strength to me.

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Finally, I would like to express my gratitude to my wife and family for their love and support throughout the years.

ABSTRACT

More than 100 species of woody and herbaceous plants are hosts of clearwing borers (Lepidoptera: Sesiidae). Injury to the living tissue of woody plants by clearwing larvae is a frequent problem in nurseries and home landscapes where damaged or stressed trees may be found. Much of their life cycle is spent beneath the bark of their host plant; thus, clearwings are considered one of the most difficult to control pests attacking trees and shrubs.

Because of the importance of the clearwing complex and the damage larvae inflict to various species of woody and herbaceous plants grown for economic or aesthetic value, a two-year study was initiated in 2000 to determine species composition, assess influence of elevation on species composition, and assess seasonality of selected species of clearwing moths in urban and forest habitats in southeastern Tennessee. Seven locations in two geographically distinct areas of the state were selected for monitoring, including five urban habitats in Hamilton County, Tennessee, and two forest habitats in the Great Smoky Mountains National Park (GSMNP).

During 2000 and 2001, 13 species, representing five genera, of adult male clearwing moths (n=18,012) were collected in pheromone-baited traps (17.4 mg 97/3 z, z-3, 13 C19 acetate/e, e-3 13 C18 acetate 91% purity) at seven sites in southeastern Tennessee. The peachtree borer, *Synanthedon exitiosa* (Say), and lilac/ash borer, *Podotesia syringae* (Harris), were the two most commonly collected species (comprising 86.49 and 10.24%, respectively, of all adult moths). An oak borer, *Paranthrene simulans*

(Grote), was more abundant in 2000 (n=339) than in 2001 (n=8), supporting other studies that demonstrate that *P. simulans* has a two-year life cycle with primary emergence in odd-numbered years. In general, lilac borer was the first species to appear in both habitats and emerged from early April to mid-July while peachtree borer generally did not emerge until late May, but remained active longer than lilac borer (mid-October).

Species composition and the influence of elevation on seasonality of the two most abundant species (lilac borer and peachtree borer) were assessed for 2000 and 2001. Among all combined urban habitats, elevation significantly influenced densities of adult lilac borers ($r^2 = 0.67$; $F = 4.28$; $df = 2, 6$; $p=0.0699$) and peachtree borers ($r^2 = 0.80$; $F = 12.46$; $df = 2, 6$; $p=0.0073$). For both species, densities were significantly greater (ca. 1.4x - 2.3x) at the low elevation than at the moderate or high elevations. However, no significant differences were detected between the moderate or high elevations. In general, densities of peachtree borer and lilac borer were lowest at the high elevation.

Data from this research suggest temperature changes among elevations may influence populations of peachtree borer and lilac borer adults. Because these differences in population densities were detected at sites close together in a geographically similar area, predictive flight phenologies of clearwing moths should be adjusted to consider elevational differences within a region or area. Additionally, continued monitoring of clearwing moths in urban and forest habitats can lead to a better understanding of emergence and species composition. This information may result in better timing of pesticide applications or other practices that support an integrated pest management approach to clearwing borer control.

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CHAPTER I

LITERATURE REVIEW

Larvae of the clearwing moth family (Lepidoptera: Sesiidae) are common, destructive pests of living tissue of woody plants (Engelhardt 1932, Potter and Timmons 1983d). In the United States and Canada, 115 species representing 19 genera of clearwing moths have been recorded, and approximately 1,135 species have been documented worldwide (Arnett 2000). Unlike most moth species, which fly at night, clearwings are day-flying moths (Nielsen 1978a).

Adults are characterized by transparent wings, which are devoid of scales (Pless and Stanley 1967), clavate or filiform antenna, and a typically slender, elongated abdomen (Snow et al. 1985). One common group characteristic is their mimicry, both in size and colorful yellow or orange markings, of various Vespidae wasps, especially *Polistes* spp. (Snow et. al. 1985). Their behavior also mimics wasps, even to the extent of pretending to sting (Arnett 2000). The combination of these morphological and behavioral characteristics provides them protection from predators (Potter and Timmons 1983c).

Adults feed only on nectar and can often be seen around flower beds (Arnett 2000). Most adults live no more than one week (Nielsen 1978b). Because the clearwing moths share so many morphological and behavioral characteristics, they are considered

less diverse than other Lepidopteran families and therefore often difficult to identify (Nielsen et al. 1975).

Adult moths lay their eggs near wounds or in bark crevices of damaged trees and shrubs (Potter and Timmons 1983d). Young larvae hatch within one to two weeks and bore into the roots, basal stalks, trunks or branches of various woody and herbaceous plants (MacKay 1968, Potter and Timmons 1983c). Larvae, which are usually white, may remain in their host plant from one to two or more years (MacKay 1968). Borer larvae tunnel and feed in living wood destroying vascular tissue and causing loss of vigor, structural weakness, branch dieback, complete girdling, and death of host plants (Potter and Timmons 1983d). Infestation sites are often marked with callus tissue, adventitious growth, or loose bark. The presence of borer excrement called frass, which may resemble sawdust, shredded wheat, or a gummy sap, and empty pupal skins protruding from the bark are positive signs of a borer infestation (Potter and Timmons 1983d).

More than 100 species of woody and herbaceous plants are hosts to clearwing borers, which are considered by many to be the most difficult to control pest attacking trees and shrubs (Nielsen 1978a, Warner and Hay 1985). Clearwings rarely attack healthy trees in their natural environment (Potter and Timmons 1983c) but rather seem to prefer trees in urban areas (Santamour and Steiner 1986), such as home lawns and nurseries. This preference of clearwing moths to urban trees often is in response to environmental (e.g., sunscald and moisture deficiency) or mechanical (e.g., lawnmower

or pruning damage) injury that leaves trees stressed and/or damaged and more susceptible to clearwing infestation (Solomon 1975, Potter and Timmons 1983c).

Clearwing moths, however, are not limited by stressed host plant availability. Solomon (1983) found that the terminal shoots of young, healthy green ash (*Fraxinus pennsylvanica* Marsh) trees are often attacked by lilac borer, also called ash borer, *Podosesia syringae* (Harris). A 1971 survey of clearwing borers on ash trees in Grand Forks, North Dakota, showed 33% of street trees damaged by these borers (see Smith-Fiola et al. 1996).

Nurseries and greenhouses generate the largest cash receipts of any crop commodity in many states, and the sale of healthy, woody landscape plants is a major component of this industry (Raupp et al. 1992). Internal feeding by larvae of various species of *Podosesia* Moschler, *Paranthrene* Hübner, and *Synanthedon* Hübner causes extensive economic impacts through decline and mortality of ornamental trees and nursery plantings (Solomon et al. 1982). One example of economic loss involves lilac, *Syringa vulgaris* L., and the damage caused by lilac borer, which can approach \$11,500 per hectare per cropping cycle in nurseries in Ohio (Nielsen and Balderston 1973). In 1989, in Georgia peach orchards, peachtree borer, *Synanthedon exitiosa* (Say), and lesser peachtree borer, *Synanthedon pictipes* (Grote and Robinson), cost growers \$1.6 million each year in crop losses and control costs and about \$20 million annually nationwide (Sanchez 1989). Currently, losses are likely to be much greater due to increased costs of production.

Many species of clearwing moths are serious pests in southeastern Tennessee. The more common species include an oak borer, *Paranthrene simulans* (Grote), rhododendron borer, *Synanthedon rhododendri* (Beutenmüller), dogwood borer, *Synanthedon scitula* (Harris), banded ash clearwing, *Podosesia aureocincta* Purrington and Nielsen, lilac borer, lesser peachtree borer, and peachtree borer. Research by Rogers and Grant (1991) in selected habitats in middle and eastern Tennessee found *Paranthrene simulans*, lilac borer, peachtree borer, rhododendron borer, lesser viburnum borer, *Synanthedon fatifera* Hodges, maple callus borer, *Synanthedon acerni* (Clemens), a borer of galls of cynipid wasps on oak, *Synanthedon decipiens* (Hy. Edwards), and dogwood borer (reported to cause economic damage to dogwoods in nurseries in middle Tennessee).

Paranthrene simulans is a pest of black oak, *Quercus velutina* Lam., red oak, *Quercus rubra* L., and pin oak, *Quercus palustris* Muench., (Snow et. al. 1985), but is reported to attack mainly mature red oaks in the south and young pin oaks in Kentucky and Ohio (Potter and Timmons 1983d). Potter and Timmons (1983d) note coarse, brown frass and areas of dark sap-stained bark on trunks and limbs as evidence of borer activity. In the south, *P. simulans* attacks are most common between the root flanges of red oak, and the damage can result in degraded timber and nursery culls (Solomon et al. 1997). *P. simulans* has a two-year life cycle, and in Tennessee and Maryland, higher numbers occur in odd-numbered years (Rogers and Grant 1991, Neal and Eichlin 1983). Emergence of *P. simulans* adults, which resemble a yellow jacket wasp (Potter and

Timmons 1983d), have been recorded to begin in late May and end in July in middle and eastern Tennessee (Rogers and Grant 1991) and Maryland (Neal and Eichlin 1983).

The rhododendron borer is a destructive pest of *Rhododendron* spp. (i.e. rhododendron, azalea) and mountain laurel, *Kalmia latifolia* L. (Neal 1982), causing damage to the trunk, branches and stems of both old, declining and young, thriving plants (Leach 1982). Larvae of this borer, one of the smallest clearwing species in North America (Neal 1981), expel an orange frass from their galleries when feeding, most noticeably in April and October (Neal 1984). This diurnal adult moth, first described in 1909 (Neal 1982), is found along the east coast from New York to South Carolina and inland to Ohio (Neal 1981). In Tennessee, rhododendron borer peaks in late May to mid-June and may be found in forest habitats as late as September (Rogers and Grant 1991).

The dogwood borer, known to exist from Canada to Florida and from Illinois to Mississippi, is commonly found wherever dogwoods, Cornaceae, are grown (Underhill 1935, Potter and Timmons 1983c) and is considered to be the most destructive insect pest of dogwood (Rogers and Grant 1990a). In 1904, G. W. Herrick first noted the dogwood borer as a pest on pecan, *Carya illinoensis* (Wang.) (Pless and Stanley 1967, Underhill 1935). It was hence named pecan borer. It is also known by other common names, such as ninebark borer, woody gall borer, oak gall borer, and at least 12 other common names, primarily because of its variety of hosts (Pless and Stanley 1967, Underhill 1935).

Besides dogwood and pecan, other host species of *S. scitula* include: oak, *Quercus* spp., ninebark, *Physocarpus opulifolius* (L.), hazel, *Corylus* sp., cherry, *Prunus* spp., apple, *Malus pumila* Miller, willow, *Salix* sp., beech, *Fagus grandifolia* Ehrh., Japanese dwarf

pine, *Pinus* sp., hickory, *Carya* sp., mountain ash, *Sorbus* sp., birch, Betulaceae, bayberry, *Myrica pennsylvanica* Loiseleur-Deslongchamps, wax myrtle, *M. cerifera* L., quince, *Cydonia oblonga* Miller, and rattan vine, *Berchemia scandens* J. Hill (Pfeiffer and Killian 1999, Eichlin and Duckworth 1988, Potter and Timmons 1983c, Pless and Stanley 1967, Underhill 1935, Engelhardt 1932).

Susceptibility of these host plants to dogwood borer is higher in less vigorous specimens or where natural or mechanical damage has provided an entry site for the borer (Pless and Stanley 1967, Rogers and Grant 1990a). Specifically with dogwood trees, borers prefer trees in full sun with severe trunk wounds, whether damaged by mowers at the base of young trees or in pruning scars or cankers in the upper limbs of older trees (Potter and Timmons 1981, Potter and Timmons 1983c). Because dogwoods in their native forest habitat are typically understory trees and less prone to mechanical damage, fewer borers are found in this habitat (Rogers and Grant 1990a).

On dogwoods, larvae generally enter the tree through damaged wood rather than healthy tissue (Riedl et al. 1985). Larvae tunnel beneath the outer bark and feed in the phloem and cambium tissue of the trunk and major limbs causing extensive damage (Pless and Stanley 1967, Potter and Timmons 1981). This feeding can partially or completely girdle the trunk or limbs (Potter and Timmons 1983a). Although it typically takes several years to completely girdle a trunk, it is possible that a single larva can girdle a dogwood in one year (Riedl et al. 1985). Trees not killed by the borer may become disfigured with callus formation or areas of dead bark and dieback may occur on limbs (Potter and Timmons 1981). In addition to dogwoods found in landscape settings,

nursery crops are also susceptible to borers. In five commercial nurseries in middle Tennessee, dogwood borers were found at infestation levels as high as 24.89% in untreated fields and 11.14% in treated fields (Rogers and Grant 1990b). Dogwood borer can cause an average damage of \$1,800/block of dogwoods as found by Rogers and Grant (1990a) in Tennessee.

Although apple has long been described as a host plant for dogwood borer, it has only been an economic pest since the introduction of clonal apple rootstocks. Clonal rootstocks develop meristematic, non-lignified tissue of burr knots, which are easily penetrated by larvae (Warner and Hay 1985, Riedl et al. 1985). Riedl et al. (1985) express concern for this situation since more than 40% of the apple hectareage in New York is on clonal rootstocks and, in their findings, about 1/3 of the rootstocks were infested by dogwood borer in western New York.

Adult emergence and flight phenology is species dependent. Underhill (1935) stated that moths are present from May to September in Virginia, which agrees with data from Kentucky (Potter and Timmons 1981). Potter and Timmons (1983c) showed two distinct emergence peaks in Kentucky. A peak in June, representing emergence from dogwood, and a second peak in August, representing emergence primarily from apple and possible other hosts (Potter and Timmons 1983c). In urban habitats and commercial nurseries in Tennessee, *S. scitula* was active from May to October and exhibited a bimodal period of emergence with the first peak occurring in mid-May and the second in early August (Rogers and Grant 1991). As with most borers, dogwood borers resemble

stinging Hymenoptera because of their dark blue color and yellow markings (Underhill 1935, Pless and Stanley 1967).

The lilac borer, which occurs throughout most of North America, west to Utah and Saskatchewan, south to Florida and Texas and north to the Canadian maritime provinces (Nielsen and Purrington 1978, Solomon 1975), causes serious damage to lilac, *Syringa vulgaris* L., privet, *Ligustrum amurense* Carr (Appleby 1973), and the French hybrid lilac, *Syringa hybrida*, (Nielsen and Balderston 1973). It is also a serious pest of ash trees (*Fraxinus* spp.), including the green ash, white ash, *F. americana* L., and Carolina ash, *F. caroliniana* Mill (Solomon 1975).

Lilac and ash trees planted in urban landscapes are seriously damaged by the larvae, which feed in the bark, cambium, and xylem tissue (Grayson 1943, Santamour and Steiner 1986, Nielsen and Balderston 1973). Host plants injured by mower damage, pruning, ice, or wind are most susceptible. Also, trees growing in open areas are more susceptible than dense stands because adult moths seem to prefer well-lighted ovipositional sites (Solomon 1975). The first noticeable external sign of damage is oozing sap mixed with fine frass from holes in the bark. Small clumps of frass are often found in bark crevices and at the base of the plant (Solomon 1975, Grayson 1943). Due to larval feeding, infested branches are often weakened and break in strong winds. If the infestation is severe, the plant may die (Appleby 1973). More likely, however, as the case with green ash, trees may decline in vigor and growth rate, lose major limbs, and lose terminal growth and become an eyesore in the landscape (Santamour 1987). When lilac borer destroys terminal shoots in timber plantations, the resulting forked or deformed

trees create unacceptable losses (Solomon et al. 2000). Santamour (1987) concluded that secondary insects and pathogens likely cause actual death of the tree. Because of the damage caused by lilac borer in northeastern Ohio, the culture of ash species has become difficult (Nielsen and Balderston 1973).

Emergence periods recorded for lilac borer are relatively similar for several areas in the United States. For example, adults were found from March to July in Mississippi (Solomon 1975), April to July in Kentucky (Potter and Timmons 1983c), and April to June in Illinois (Appleby 1973). These dates correspond closely to the first bloom of doublefile, *Viburnum plicatum* Thunb., and blackhaw, *Viburnum prunifolium* L., viburnums which are often used as key indicators of adult emergence (Herms 1990).

The thorax and abdomen of the male lilac borer are brownish black and are highlighted with chestnut red markings (Solomon 1975). The female is similar in color but highlighted with indistinct reddish-orange markings (Timmons and Potter 1981). Both are mimics of *Polistes* spp. (Hymenoptera: Vespidae) in appearance and size (Nielsen and Purrington 1978).

The banded ash clearwing closely resembles *P. syringae* and is considered to be an isolated sibling species (Purrington and Nielsen 1977). *Podosesia aureocincta* feeds on ash and the overlap of this plant host and close resemblance has led to considerable confusion between the two species (Potter and Timmons 1983c). Banded ash clearwing is distinguishable from lilac borer by its narrow, bright, orange-yellow band on the fourth abdominal segment (Purrington and Nielsen 1977) and because it does not emerge until August and September, well after the last flight date of lilac borer (Potter and Timmons

1983c, Nielsen and Purrington 1974, Purrington and Nielsen 1977). The distribution shown by Purrington and Nielsen (1977) noted that banded ash clearwing ranges from New York City south to Central Florida and west to Indiana and Oklahoma.

The lesser peachtree borer is a pest of home and orchard plantings of peach, *Prunus persica* Batsch, and cherry, *Prunus* sp. (Meyer 1982). The lesser peachtree borer shows a preference for older trees and generally oviposits on the upper trunk and branches that have received environmental, disease, or mechanical damage (i.e., winter injury, cankers, and pruning) (Potter and Timmons 1983c). Because of the ability of lesser peachtree borer to damage injured trees, Pfeiffer et al. (1991) report this clearwing as a major contributor to the decline of peach trees in New York and Pennsylvania. Data provided by Pfeiffer et al. (1991) contrast data from southern states (Kentucky and Georgia) where peachtree borer is the primary peach pest (Potter and Timmons 1983c).

The adult lesser peachtree borer is active during most of the growing season for peach in the upper coastal plains of Georgia (Dupree 1973). Emergence data from Georgia show first flight of adults in April with a seasonal peak in May and continued emergence through the summer (Dupree 1973). These dates correspond closely to the first bloom of 'Winter King' hawthorne (*Crataegus viridis* 'Winter King'), which is often used as a key indicator of adult emergence (Herms 1990). Data from Kentucky and Ohio also indicate a heavy flight from May through summer (Gorsuch and Karandinos 1974, Potter and Timmons 1983c).

The peachtree borer is considered one of the most important species of Sesiidae because of the damage it causes to both cultivated and wild *Prunus* spp. (i.e., peach,

flowering cherry, almond, and plum) (Potter and Timmons 1983c, Snow et al. 1985).

Peachtree borers regularly cause economic loss to *Prunus* spp. in orchards and landscapes by feeding on the cambium and inner bark from the root crown to just above soil level (Reilly et al. 1987, Potter and Timmons 1983c). Reilly et al. (1987) state that small and large roots of both young and old trees are subject to borer injury. The larva, which undergoes seven instars (Smith 1965), completes its life cycle in one year throughout most of its range, although in northern areas, some larvae may require two years (Gentry et al. 1978). In most cases, first emergence of adult peachtree borer occurs in May and last emergence ranges from August in Kentucky (Potter and Timmons 1983c), September in Tennessee (Rogers and Grant 1991), and October in South Carolina (Gentry et al. 1978).

The adult male peachtree borer typically emerges before females by as much as one week (Gentry et al. 1978, Jacklin and Yonce 1969). Adults are diurnal and sexually dimorphic; both sexes resemble wasps physically and in flight behavior (Barry and Nielsen 1984). Butler (1931) states that adult peachtree clearwings may live from two to nine days.

Since the development of commercially available clearwing pheromones in 1979, pheromone traps have become a valuable new tool in increasing our understanding of sesiid biology, behavior, and evolution (Duckworth and Eichlin 1977, Timmons and Potter 1981). For example, synthetic pheromones used to attract rhododendron borer have led to determining correct flight times and expanded distribution of this moth (Neal 1982). Also, in research by Gentry et al. (1977) on peachtree borer and lesser peachtree

borer, pheromones proved more effective than traps baited with virgin females in their ability to capture higher numbers of both species (Barry et al. 1978).

Pheromones have also led to the discovery of new species of clearwings, including the rare *Carmenta odda* Duckworth and Eichlin first found in South Carolina (Brown and Snow 1986) and several new species in the western hemisphere (Eichlin and Taft 1988). Additionally, pheromones have proven an effective tool in documenting the presence of viburnum borer, *Synanthedon viburni* Engelhardt, and *S. scitula* in an expanded western host range (Meyer et al. 1988). Commercially manufactured pheromones used in nurseries and orchards enable growers to monitor flight activity of several species of moths to make well-timed chemical treatments while reducing unnecessary applications (Nielsen 1978a, Ascerno 1991, Raupp 1985). Besides their monitoring effectiveness, pheromone traps and pheromone suppression tools have also been shown to suppress borer populations in nurseries, orchards, or home landscapes (Timmons and Potter 1981, Pfeiffer et al. 1991).

Insect phenology is another precise method used to establish accurate timing of insecticide applications. This method is based on the growth and development of insects as related to weather conditions, specifically temperature. The temperature effect is often recorded in degree-days - units that measure the length of time that temperatures were above the minimum temperature level where growth and development can occur for specific insects in a 24-hour period. These measurements are helpful to better time insecticide treatments; however, clearwing populations may vary greatly from one geographical area to another, and therefore it may be necessary to establish degree-day

models for individual areas (Ascerno 1991). Likewise, data for degree-day models may vary due to elevational differences.

Using degree-day modeling in conjunction with pheromone-trap observations, Johnson and Mayes (1984) found that 50% of the peachtree borers in a peach orchard in Arkansas were collected at an average cumulative degree-day value of 1,291. Potter and Timmons (1983b) found that lilac borer flights began in urban, forest, and commercial sites after average degree-day accumulations of 168.9 and 189.9, in Lexington and Louisville, Kentucky, respectively. A 10% capture level was recorded when average degree-day accumulations were 281.9 in Lexington and 278.9 in Louisville. Using degree-day modeling, lilac borer adult activity was found to peak in June and cease by 1 August in Ohio, North Dakota, and other northern states (Johnson and Lyon 1991).

If data were available that forecast dates when pests have reached vulnerable stages, growers and landscapers would have a valuable tool that would allow for precise timing of insecticides. With precise applications, insecticides with shorter residual properties, lower dosages of material, or with selective activity towards specific growth stages (i.e., egg or first-instar larva) could be included as a key component in an effective integrated pest management program (Herms 1990).

Because little is known on seasonality or degree-days and the effect of elevation on emergence of clearwing borers in southeastern Tennessee, a two-year study was initiated to address these issues. The specific objectives of this research were to:

1. determine species composition and seasonality of clearwing moths in southeastern Tennessee, and

2. assess influence of elevation on emergence, seasonal incidence, and species composition of clearwing moths.

CHAPTER II

SEASONAL INCIDENCE AND SPECIES COMPOSITION OF CLEARWING MOTHS IN URBAN LANDSCAPES AND FOREST HABITATS IN SOUTHEASTERN TENNESSEE

i. INTRODUCTION

More than 100 species of woody and herbaceous plants can be attacked by larvae of clearwing moths (Lepidoptera: Sesiidae). Feeding injuries by larvae of clearwing moths is a frequent problem in nurseries and home lawns where damaged or stressed trees may be found (Solomon 1975, Potter and Timmons 1983c). Because much of their life cycle is spent beneath the bark of their host plant, clearwings are considered one of the most difficult pest groups to control (Nielsen 1978a, Warner and Hay 1985). Species of *Podosesia* Möschler, *Paranthrene* Hübner, and *Synanthedon* Hübner are described by Solomon et al. (1982) as “notorious for economic damage” in ornamental and nursery plantings.

The availability of synthetic lures (i.e., pheromones) has allowed researchers to improve their understanding of sesiid biology (Duckworth and Eichlin 1977) while discovering new species and distribution ranges (Brown and Snow 1986, Meyer et al. 1988, Eichlin and Taft 1988, Neal 1982). Since pheromone traps have been used as monitoring devices, insecticide applications against many borer species, such as

peachtree borer, *Synanthedon exitiosa* (Say), have been more accurately timed while reducing many unnecessary applications (Nielsen 1978a).

Few studies have been conducted using synthetic pheromones in Tennessee, although Rogers and Grant (1991) have reported on seasonal incidence and infestation levels of dogwood borer, *Synanthedon scitula* (Harris), and seven other clearwing borer species in selected urban, forest, and commercial habitats in middle and eastern Tennessee. Because little information is available on clearwing moths, a two-year study was initiated to monitor the incidence and species composition of clearwing moths in urban landscapes and forest habitats of southeastern Tennessee.

ii. MATERIALS AND METHODS

Seasonal incidence of adult clearwing moths was monitored, using pheromone traps, at seven locations in two geographically distinct areas of the state. These included: 1) five urban habitats in Hamilton County, in southeastern Tennessee (from 21 April to 13 October 2000 and from 16 April to 12 October 2001) and 2) two forest habitats in the Great Smoky Mountains National Park (GSMNP), Blount County, in eastern Tennessee (from 11 May to 21 September 2000 and from 25 April to 26 September 2001) (Table 1). Specific information about habitat characteristics at each site is provided in the Appendix.

The five sites in the urban habitat were selected based on the abundance of host plants and varying degrees of landscape maintenance. Three of the urban sites (Sites 1, 2, and 3) were located on Lookout Mountain, Tennessee. Site 1 was ca. 7.56 km from Site 2

Table 1. Elevation, global positioning system (GPS) coordinates, trap placement, location, description, and characteristics of pheromone trapping sites in southeastern Tennessee.

Site (Elevation)	Trap	GPS Coordinates	Trap Placement	Location	Description
Site 1 (228 m)	1	N 35.00.487/ W 85.21.876	Rhododendron	Lookout Mountain – Reflection Riding Arboretum and Botanical Garden	Maintained Park
	2	N 35.00.452/ W 85.21.996	Hemlock		
	3	N 35.00.166/ W 85.22.070	Tulip Poplar		
Site 2 (499 m)	1	N 35.00.336/ W 85.20.326	Spiriea	Lookout Mountain – Home Landscape	Maintained Landscape
	2	N 35.00.328/ W 85.20.341	Rhododendron		
	3	N 35.00.316/ W 85.20.355	Hemlock		
Site 3 (651 m)	1	N 34.59.716/ W 85.21.170	Holly	Lookout Mountain – The Commons	Maintained Park
	2	N 34.59.686/ W 85.21.249	Holly		
	3	N 34.59.654/ W 85.21.237	Pine		
Site 4 (553 m)	1	N 35.05.186/ W 85.22.320	Pine	Elder Mountain – Home Landscape	Maintained Landscape
	2	N 35.05.236/ W 85.22.317	Sweet Gum		
	3	N 35.05.264/ W 85.22.400	Rhododendron		
Site 5 (207 m)	1	N 35.07.525/ W 85.12.136	Rhododendron	Hixson – Home Landscape	Maintained Landscape
	2	N 35.07.517/ W 85.12.170	Rhododendron		
	3	N 35.07.543/ W 85.12.174	Rhododendron		
Site 6 (553 m)	1	N 35.41.153/ W 83.29.940	Unavailable*	Great Smoky Mountains National Park – Twin Creeks	Non-maintained Natural Area in National Park
	2	N 35.41.166/ W 83.30.090	Unavailable		
	3	N 35.41.247/ W 83.30.017	Unavailable		
Site 7 (372 m)	1	N 35.38.452/ W 83.41.490	Unavailable	Great Smoky Mountains National Park – Tremont	Non-maintained Natural Area in National Park
	2	N 35.38.508/ W 83.41.391	Unavailable		
	3	N 35.38.636/ W 83.41.422	Unavailable		

* Trap placements in the Great Smoky Mountains National Park were not recorded.

and ca. 9.82 km from Site 3, and Site 2 was ca. 2.25 km from Site 3. Site 1 was located at Reflection Riding Arboretum and Botanical Garden and categorized as a maintained park because grounds crew provided general maintenance (i.e., mowing, pruning, planting new trees and shrubs). Azalea, rhododendron, dogwood, and many other native plant species were abundant. Pheromone traps were spaced from 239 m to 773 m apart. Site 2 was located in a home landscape and categorized as a maintained landscape. Azaleas and rhododendrons dominated the plant species at this site. Pheromone traps were spaced from 29 m to 66 m apart. Site 3 was located at The Commons, a 5.27 ha park owned by the City of Lookout Mountain, and categorized as a maintained park since grounds crew provided general maintenance similar to Site 1. The landscape consists of various native and introduced trees, shrubs, and perennials. Pheromone traps were spaced from 75 m to 171 m apart.

A fourth monitoring site (Site 4) was located on Elder Mountain, Tennessee, and categorized as a maintained landscape. Prior to 1996, this site was a nursery for rhododendrons and azaleas, and as such these two shrubs are prevalent. This site also has an abundance of various oak species. Pheromone traps were spaced from 96 m to 205 m apart. Site 4 was ca. 13.03 km from the closest site on Lookout Mountain (Site 1) and 40.87 km from the fifth site (Site 5) in Hixson, Tennessee.

The fifth site, located in a home landscape, was categorized as a maintained landscape. This landscape consisted primarily of rhododendrons and azaleas, but dogwoods, grapevines, and oaks also were prevalent. Pheromone traps were spaced from

57 m to 68 m apart. Site 5 was ca. 31.05 km from the closest site on Lookout Mountain (Site 1).

Two sites were selected in the GSMNP in eastern Tennessee to provide information on adult Sesiidae in a forest habitat. One site (Site 6) was located near the Ranger Station at Twin Creeks, and Site 7 was located near the Ranger Station at Tremont.

Three pheromone traps were placed at each of the seven sites and positioned 60 to 152 cm above the ground surface with similar lighting conditions, primarily diffused shade. Each pheromone trap consisted of a Biocontrol Services Multipher I bucket trap (Great Lakes IPM, Vestaburg, Michigan) with a white base (203 mm deep by 140 mm wide at the top and 102 mm wide at the bottom) and green cover (267 mm wide). Traps were baited with a lure strip impregnated with 17.4 mg 97/3 z, z-3, 13 C19 acetate/e, e-3, 13 C18 acetate 91% purity (Scentry Biologicals, Billings, Montana). One strip (2.54 x 5.08 cm) of Hercon vapor tape (10% DDVP) was placed at the bottom of each trap to quickly kill and prevent damage to the identification features (e.g., wings, legs, and antennae) of adult moths.

Traps were monitored weekly from mid-April to early September and bimonthly from mid-September to mid-October in the urban sites and weekly from late April to late September in the forest sites. On each sampling date, adults were removed from the traps, placed in a labeled Ziploc® bag (900 ml), and taken to the laboratory where they were sorted, processed, and identified to species when possible. Dr. T. D. Eichlin of the California Department of Food and Agriculture Plant Pest Diagnostics Branch in

Sacramento, California, and Greg Wiggins and Adriean Mayor, both of the University of Tennessee, assisted with species confirmation and/or identification. Voucher specimens from both habitats will be incorporated into the University of Tennessee Insect Museum, and representative vouchers collected from the two forest habitats will be deposited with the GSMNP. Traps were baited with a fresh pheromone lure and Hercon vapor tape at the beginning and middle of each trapping year.

Species composition and seasonal incidence of clearwing moths collected at each site were compiled and compared for each year. Data were analyzed using SAS (SAS 1999) to assess differences among the sites ($p \leq 0.05$; Tukey's Studentized Range test).

iii. RESULTS AND DISCUSSION

SPECIES COMPOSITION

Year 2000

During 2000, 10,475 adult male sesiid moths, representing five genera and 13 species, were collected in pheromone-baited traps in urban and forest habitats (Table 2). The sesiid species trapped included the: lilac borer (also called ash borer), *Podosesia syringae* (Harris), banded ash clearwing, *Podosesia aureocincta* Purrington and Nielsen, peachtree borer, *Synanthedon exitiosa* (Say), rhododendron borer, *S. rhododendri* (Beutenmüller), black gum borer, *S. rubrofascia* (Hy. Edwards), dogwood borer, *S. scitula* (Harris), a *Betula* borer, *S. fulvipes* (Harris), lesser viburnum borer, *S. fatifera* Hodges, a holly borer, *S. kathyae* Duckworth and Eichlin, an oak borer, *Paranthrene*

Table 2. Species composition of male clearwing moths (Sesiidae) collected in pheromone-baited traps in urban (Chattanooga) and forest (Great Smoky Mountains National Park) habitats in southeastern Tennessee during 2000 and 2001.

Species	Common Name	2000		2001		2-Year Total	
		n	% Composition	n	% Composition	n	% Composition
<i>Synanthedon exitiosa</i>	Peachtree Borer	9,555	91.22	6,023	79.91	15,578	86.49
<i>Podosesia syringae</i>	Lilac Borer	811	7.74	1,034	13.72	1,845	10.24
<i>Podosesia aureocincta</i>	Banded Ash Clearwing	14	0.13	55	0.73	69	0.38
<i>Synanthedon fatifera</i>	Lesser Viburnum Borer	27	0.26	36	0.48	63	0.34
<i>Synanthedon rhododendri</i>	Rhododendron Borer	33	0.31	26	0.34	59	0.33
<i>Paranthrene simulans</i>	None	8	0.08	339	4.50	347	1.92
<i>Carmenta bassiformis</i>	None	12	0.11	18	0.24	30	0.17
<i>Synanthedon kathyae</i>	None	3	0.03	0	0.00	3	0.02
<i>Synanthedon scitula</i>	Dogwood Borer	1	0.01	1	0.01	2	0.01
<i>Synanthedon rubrofascia</i>	Black Gum Borer	1	0.01	0	0.00	1	0.01
<i>Synanthedon fulvipes</i>	None	8	0.08	5	0.07	13	0.07
<i>Carmenta ithacae</i>	None	1	0.01	0	0.00	1	0.01
<i>Alcathoe caudata</i>	Clematis Borer	1	0.01	0	0.00	1	0.01
TOTALS		10,475	100.00	7,537	100.00	18,012	100.00

simulans (Grote), a borer of ironweed, *Carmenta bassiformis* (Walker), a borer of *Helenium* and *Heliopsis* spp., *Carmenta ithacae* (Beutenmüller), and clematis borer, *Alcathoe caudata* (Harris). *Synanthedon scitula*, *S. rubrofascia*, *C. ithacae*, and *A. caudata* were collected only as single specimens in 2000.

The peachtree borer was the most commonly collected species (n=9,555) and represented 91% of all adults collected during 2000 (Table 2). The lilac borer was the second most commonly collected species (n=811) and represented only ca. 8% of all adults collected. The remaining 11 species were collected in low numbers and collectively compiled only 1% (n=109) of all specimens.

Year 2001

During 2001, 7,537 adult male sesiid moths, representing four genera and nine species, were collected from urban and forest habitats (Table 2). The species collected were the: lilac borer, banded ash clearwing, peachtree borer, rhododendron borer, dogwood borer, lesser viburnum borer, *P. simulans*, *S. fulvipes*, and *C. bassiformis*. Although low numbers of adults of *S. kathyae*, *S. rubrofascia*, *C. ithacae*, and *A. caudata* were collected in 2000, none of these species were collected in 2001. *S. scitula* was collected as a single specimen again in 2001.

The peachtree borer (n=6,023) and lilac borer (n=1,034) were again the most commonly collected clearwing species, representing ca. 80% and 14%, respectively, of all specimens. *P. simulans*, was collected in greater numbers in 2001 (n=339) than in 2000 (n=8) and accounted for ca. 5% of all adult males captured. The remaining six species collectively comprised ca. 1% (n=141) of all adult clearwing moths.

Year 2000 and 2001 Combined

During this two-year study, *S. exitiosa* and *P. syringae* were the two most commonly collected species comprising 15,578 (86.5%) and 1,845 (10.2%), respectively, of moths collected during both years (n=18,012) (Table 2). *P. simulans* was ca. 42.4x more abundant in 2001 (n=339) than in 2000 (n=8), supporting previous reports that document a two-year life cycle for *P. simulans* with primary emergence in odd-numbered years (Rogers and Grant 1991, Neal and Eichlin 1983). Taft et al. (1991), however, suggests that *P. simulans* is synchronized to emerge in even-numbered years, which is not supported by the findings in southeastern Tennessee. The banded ash clearwing also was slightly (ca. 4x) more abundant in 2001 (n=55) than in 2000 (n=14). These numbers are not different enough to suggest a two-year cycle; however, this slight difference in population numbers may be partially related to environmental conditions.

HABITAT

Urban Habitat

Ten species of clearwing moths, representing four genera, were collected from the urban habitats during this two-year study. Two species, *S. exitiosa* and *P. syringae*, represented 98.5% (90.32 and 8.18%, respectively) (n=16,177) of the total number of moths (n=16,423) collected in urban habitats in 2000 and 2001 (Table 3). *Paranthrene simulans*, *Podosesia aureocincta*, *S. rhododendri*, *S. rubrofascia*, *S. fatifera*, *S. kathyae*, *S. scitula*, and *C. bassiformis* collectively comprised the remaining 1.5% (n=246) of all moths collected in the urban habitats.

Table 3. Species composition of male clearwing moths (Sesiidae) collected in pheromone-baited traps in urban habitats in southeastern Tennessee during 2000 and 2001.

Species	Common Name	2000		2001		2-Year Total	
		n	% Composition	n	% Composition	n	% Composition
<i>Synanthedon exitiosa</i>	Peachtree Borer	9,141	93.43	5,692	85.74	14,833	90.32
<i>Podosesia syringae</i>	Lilac Borer	564	5.76	780	11.75	1,344	8.18
<i>Podosesia aureocincta</i>	Banded Ash Clearwing	14	0.14	54	0.81	68	0.41
<i>Synanthedon fatifera</i>	Lesser Viburnum Borer	27	0.28	36	0.54	63	0.38
<i>Synanthedon rhododendri</i>	Rhododendron Borer	30	0.31	26	0.39	56	0.34
<i>Paranthrene simulans</i>	None	3	0.03	47	0.71	50	0.31
<i>Carmenta bassiformis</i>	None	0	0.00	3	0.05	3	0.02
<i>Synanthedon kathyae</i>	None	3	0.03	0	0.00	3	0.02
<i>Synanthedon scitula</i>	Dogwood Borer	1	0.01	1	0.01	2	0.01
<i>Synanthedon rubrofascia</i>	Black Gum Borer	1	0.01	0	0.00	1	0.01
TOTALS		9,784	100.00	6,639	100.00	16,423	100.00

During this two-year study, only one specimen of *S. rubrofascia* was collected from any of the urban sites (Site 3). The capture of this species was unexpected at Site 3, a rocky site with shallow soil at a high elevation on Lookout Mountain, since *S. rubrofascia* is more likely found where *Nyssa* spp. (i.e., sour gum, sweet gum, and tupelo) grow in low acid and wet bottom land (Snow et. al. 1985). However, Snow et. al. (1985) found *S. rubrofascia* to be the second most collected species and the second most widely distributed species during a two-year study in central Georgia. The Georgia study included 52 different trapping sites (i.e., swamps, forests, and pastures), and *S. rubrofascia* was found at 38 of the sites. Therefore, the fact that only one specimen of *S. rubrofascia* was collected in southeastern Tennessee may be more likely related to the pheromone used in this study rather than site location.

Densities of peachtree borer were significantly different among urban sites in 2000 ($r^2 = 80.9$; $F = 15.43$; $df = 2, 269$; $p < 0.0001$), 2001 ($r^2 = 88.2$; $F = 5.74$; $df = 4, 10$; $p = 0.0115$), and both years combined ($r^2 = 91.0$; $F = 14.45$; $df = 4, 10$; $p = 0.0004$) (Table 4). In general, densities were greatest at Site 5, a home landscape site, and lowest at Site 3, a maintained park on Lookout Mountain. No significant differences ($p > 0.05$) were detected among populations of lilac borer at any site during the two-year study.

Forest Habitat

In the forest habitat, ca. 97% of the moths collected in 2000 and 2001 consisted of three species: *S. exitiosa* (ca. 47%), *P. syringae* (ca. 32%), and *P. simulans* (ca. 19%) (Table 5). The percentages of these three species differed greatly among habitats due to specimen abundance, host plant availability, and habitat preferences. These differences

Table 4. Densities of lilac borer, *Podosesia syringae*, and peachtree borer, *Synanthedon exitiosa*, at five sites in southeastern Tennessee during 2000 and 2001.

Site	2000		2001		Both Years	
	Lilac Borer	Peachtree Borer	Lilac Borer	Peachtree Borer	Lilac Borer	Peachtree Borer
1 [§]	2.77 ± 6.25* a [†]	20.88 ± 23.60 bc	3.90 ± 7.92 a	15.58 ± 20.11 ab	3.35 ± 7.14 a	18.18 ± 21.97 b
2	1.04 ± 2.14 a	27.19 ± 27.75 b	1.06 ± 2.21 a	12.67 ± 16.72 b	1.05 ± 2.17 a	19.77 ± 23.85 b
3	0.91 ± 1.87 a	15.67 ± 18.59 c	1.71 ± 3.30 a	9.17 ± 11.36 b	1.32 ± 2.72 a	12.35 ± 15.62 b
4	1.12 ± 1.99 a	24.74 ± 30.82 bc	1.78 ± 4.42 a	12.75 ± 18.79 b	1.46 ± 3.46 a	18.57 ± 25.97 b
5	2.35 ± 5.72 a	44.36 ± 41.26 a	2.39 ± 4.67 a	28.89 ± 32.11 a	2.37 ± 5.19 a	36.46 ± 37.55 a

[§] Site 1= Lookout Mountain, Reflection Riding Arboretum and Botanical Garden

Site 2= Lookout Mountain, Home Landscape

Site 3= Lookout Mountain, The Commons

Site 4= Elder Mountain, Home Landscape

Site 5= Hixson, Home Landscape

* Values represent average number of moths/three traps/week (two sites each at low and moderate elevations; one site at the high elevation).

[†] Values within a column followed by the same letter are not significantly different ($P > 0.05$) (Tukey's Studentized Range test).

Table 5. Species composition of male clearwing moths (Sesiidae) collected in pheromone-baited traps in forest habitats in southeastern Tennessee during 2000 and 2001.

Species	Common Name	2000		2001		2-Year Total	
		n	% Composition	n	% Composition	n	% Composition
<i>Synanthedon exitiosa</i>	Peachtree Borer	414	59.91	331	36.85	745	46.89
<i>Podosesia syringae</i>	Lilac Borer	247	35.75	254	28.29	501	31.53
<i>Paranthrene simulans</i>	None	5	0.72	292	32.52	297	18.69
<i>Carmenta bassiformis</i>	None	12	1.74	15	1.67	27	1.70
<i>Synanthedon fulvipes</i>	None	8	1.16	5	0.56	13	0.82
<i>Synanthedon rhododendri</i>	Rhododendron Borer	3	0.44	0	0.00	3	0.19
<i>Carmenta ithacae</i>	None	1	0.14	0	0.00	1	0.06
<i>Alcathoe caudata</i>	Clematis Borer	1	0.14	0	0.00	1	0.06
<i>Podosesia aureocincta</i>	Banded Ash Clearwing	0	0.00	1	0.11	1	0.06
TOTALS		691	100.00	898	100.00	1,589	100.00

are especially relevant to *S. exitiosa* which is more commonly found in urban settings (i.e., nurseries and orchards). *Podosesia aureocincta*, *C. bassiformis*, *C. ithacae*, *A. caudata*, *S. rhododendri*, and *S. fulvipes* were collected in low numbers and collectively comprised the remaining moths (ca. 3%) from the forest habitat during this two-year study. Only single specimens of *C. ithacae*, *A. caudata*, and *P. aureocincta* were collected during both years.

Synanthedon fulvipes and *A. caudata* were collected in the forest habitat but were not collected in the urban habitat. *Alcathoe caudata* is a pest of *Clematis virginiana* L. (Eichlin and Duckworth 1988), a native clematis found at wood edges, in thickets, and along stream banks, which may explain why this species was only found in the forest habitat. As in this study, Rogers and Grant (1991) collected no *S. scitula* specimens from the forest habitat, suggesting that dogwood borer is more likely an urban pest.

Both Habitats Combined

During this two-year study, *S. exitiosa* was ca. 20x more abundant in urban habitats (n=14,833) (Table 3) than in forest habitats (n=745) (Table 5). This difference in population densities may be attributed to the fact that *Prunus* spp. in landscape settings are often more likely to be damaged by equipment during regular maintenance. This damage results in more attractive and more numerous ovipositional sites in urban habitats compared to those in forest habitats. In a previous study in Tennessee (Rogers and Grant 1991), peachtree borer was not collected from forest habitats and it was therefore suggested, based on a 1946 publication by G. P. Englehardt, that the peachtree borer may show preference for cultivated peach over native *Prunus* spp.

Podosesia syringae moths were found 3x more often in urban habitats (n=1,344) (Table 3) than in forest habitats (n=501) (Table 5). Similar results were found by Rogers and Grant (1991) where *P. syringae* represented 70% of the moths collected in commercial and urban habitats but only 42% in forest habitats.

Conversely, adult *P. simulans* were found in the forest habitat (n=297) (Table 5) ca. 6x more often than in the urban habitats (n=50) (Table 3). This difference may be explained by the lower numbers of suitable host plants in the urban habitats. Even though numerous mature species of oaks occur in urban habitats (Appendix), Eichlin and Duckworth (1988) state that the young shoots and saplings of black, white, and red oaks are often preferred ovipositional sites for *P. simulans*. It is likely that oak saplings were found more abundant in the deciduous, hardwood forest habitats than the urban habitats, therefore contributing to the difference in population densities of *P. simulans*.

Densities of peachtree borer adults declined from 2000 to 2001- ca. 23% decline among the urban sites and ca. 11% among the forest sites. However, from 2000 to 2001, densities of lilac borers increased ca. 16%, among the five urban sites and ca. 1% among the two forest sites. These changes may be related to changes in environmental conditions, such as temperature, between the two years.

Carmenta bassiformis was not collected at any of the five urban habitats; however, 12 males were collected at one site (Site 6; Twin Creeks) in the forest habitat. *C. bassiformis* attacks the roots of wild ironweed, *Veronia noveboracensis* L., *V. crinita* Rafinesque, and Joe-pye-weed, *Eupatorium purpureum* L. (Taft et al. 1991, Eichlin and

Duckworth 1988). These plant species are not commonly found in managed landscapes, and therefore may explain the lack of specimens at the urban sites.

Fourteen male banded ash clearwing moths were collected from the urban sites. This species was not collected at either forest habitat. Although lilac borer has been found in lilac, ash, privet, and other oleaceous hosts, its sibling species, the banded ash clearwing, has only been recorded in ash trees (Purrington and Nielsen 1977). Therefore, it is likely that a lack of sufficient host plants led to the resulting low numbers collected.

Synanthedon fatifera, *S. kathyae*, *S. scitula*, and *S. rubrofascia* were collected in the urban habitat but were not collected in the forest habitat. The lack of *S. fatifera* species in the forest habitat differs from other studies that show this species to be more abundant in forest habitats (Neal and Eichlin 1983, Rogers and Grant 1991). *Synanthedon kathyae* is reported as a pest on ornamental holly trees (Eichlin and Duckworth 1988) and would therefore be expected to be encountered in an urban habitat.

Seven species, *P. aureocincta*, *C. bassiformis*, *C. ithacae*, *S. kathyae*, *S. rubrofascia*, *S. fulvipes*, and *A. caudata*, were collected during this two-year study that were not reported in a previous study in middle and eastern Tennessee (Rogers and Grant 1991). The differences in species composition are most likely due to the type of pheromone used in this and the 1991 study. *S. fulvipes* was recorded as a new park record in the Great Smoky Mountains National Park.

The low incidence of dogwood borers or any other species of clearwing moth in these pheromone traps should not be interpreted as an overall low species population, which may result in the generalization that a clearwing species, such as dogwood borer, is

not a pest in urban landscapes in southeastern Tennessee. Low numbers of any species collected, such as the dogwood borer, may be due to the type of pheromone used in this study. For example, Braxton and Raupp (1995) found in Maryland that the same pheromone (Scentry SC-K103) used in this study yielded no catches of dogwood borer in their study. Further evidence is provided by Rogers and Grant (1991) who captured 613 dogwood borers representing ca. 9% of their total collection from sites in urban and commercial habitats using a different pheromone. As in this study, Rogers and Grant (1991) collected no dogwood borer specimens from the forest habitat.

SEASONAL INCIDENCE

Each sessid species emerges and is active at specific times during the year (Taft et al. 1991, Eichlin and Duckworth 1988). Differences in adult emergence, activity, and seasonality may be influenced by many factors, including proximity of host plant to trap, number of traps, weather, or natural enemies (Braxton and Raupp 1995, Sharp et al. 1978). Therefore, the flight phenologies of the 13 species collected in urban and forest habitats in Tennessee were assessed from April 2000 to October 2001 (Fig. 1).

Podotesia syringae was the first species collected each year and was found generally in early April to the middle of July (Fig. 1). In the urban sites during 2000, *P. syringae* was active the first week of trapping, 21 April, and reached peak flight at most sites between 4 and 19 May (Fig. 2). No moths were collected from any of the five sites after 21 July. Similar results were found in 2001, when adult *P. syringae* were collected from mid-April to early July (Fig. 3). Peak emergence of adult moths occurred between 28 April and 5 May. In the forest habitat during 2000, *P. syringae* were collected from

Species	Month						
	Apr	May	Jun	Jul	Aug	Sept	Oct
<i>Podosesia syringae</i>	—	—	—	—			
<i>Synanthedon exitiosa</i>		—	—	—	—	—	—
<i>Synanthedon fulvipes</i>		—					
<i>Paranthrene simulans</i>		—	—	—			
<i>Synanthedon rhododendri</i>		—	—	—			
<i>Synanthedon fatifera</i>			—	—			
<i>Synanthedon rubrofascia</i>			—				
<i>Carmenta bassiformis</i>			—	—	—		
<i>Synanthedon scitula</i>			—	—			
<i>Synanthedon kathyae</i>			—				
<i>Alcathoe caudata</i>			—				
<i>Carmenta ithacae</i>				—			
<i>Podosesia aureocincta</i>				—	—	—	—

Fig. 1. Seasonal incidence of male Sesiidae collected in pheromone-baited traps in southeastern Tennessee during 2000 and 2001.

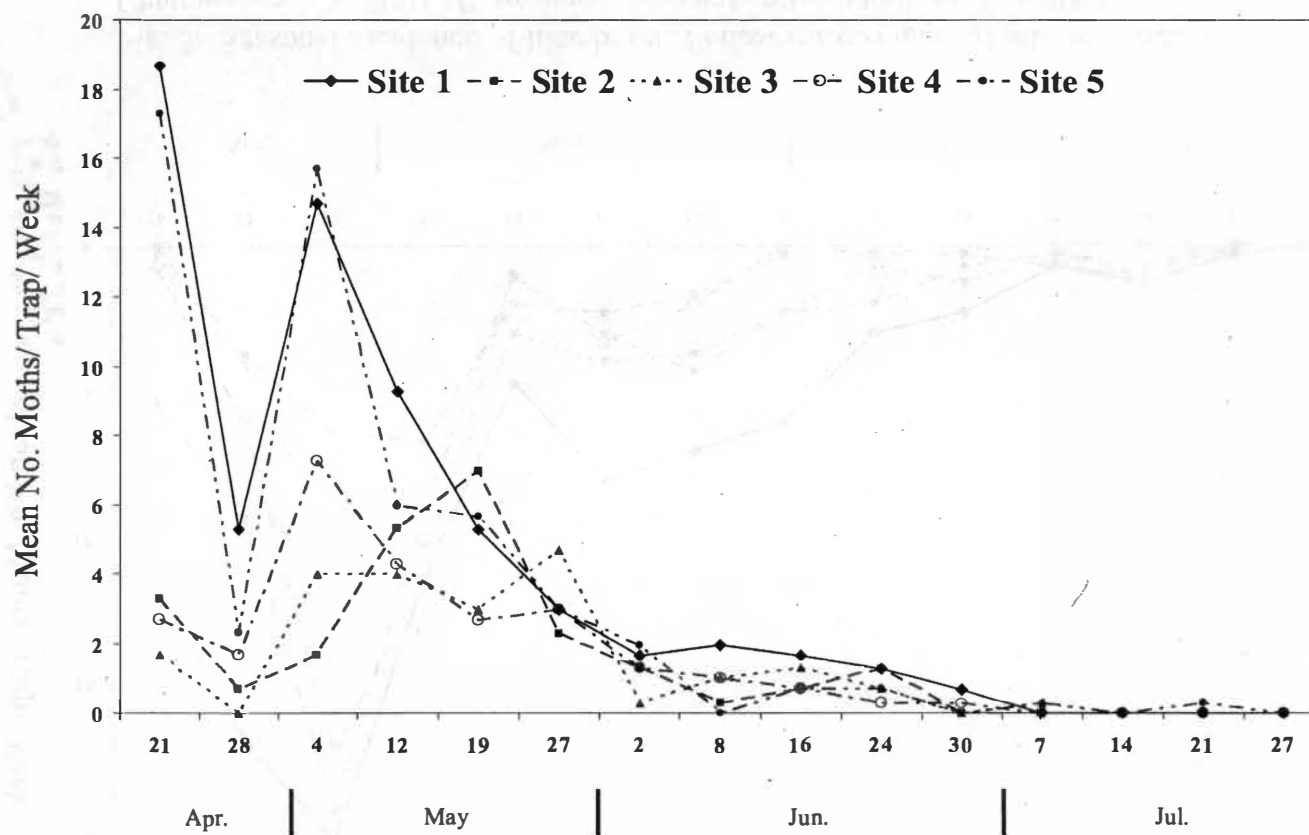


Fig. 2. Seasonal incidence of lilac borer, *Podosesia syringae*, at selected sites near Chattanooga, TN, 2000 (*P. syringae* were not collected after 21 July 2000).

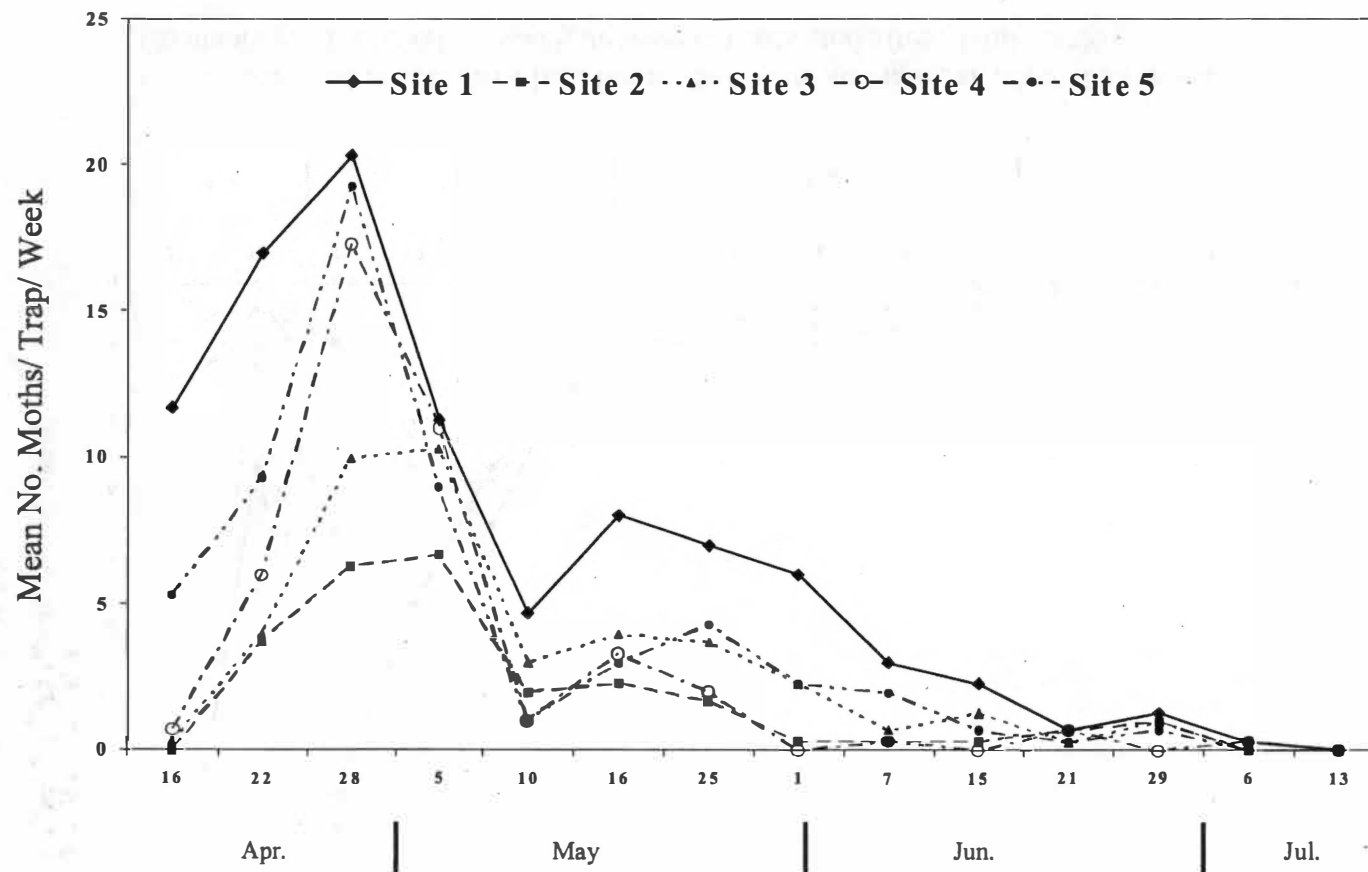


Fig. 3. Seasonal incidence of lilac borer, *Podosesia syringae*, at selected sites near Chattanooga, TN, 2001 (*P. syringae* were not collected after 6 July 2001).

early May until late July (Fig. 4). Peak emergence during 2000 occurred on 11 May and on 12 June. In 2001, adult moths were collected from late April to mid-July, with peak emergence ranging from early to mid-May (Fig. 5). In both habitats, in both years, adult male *P. syringae* were already active when traps were first placed in the field; therefore, it is difficult to estimate exactly when emergence of this species begins. A previous two-year study in Tennessee (Rogers and Grant 1991) also found *P. syringae* to be the first species collected both years and recorded capture from mid-April to mid-July. *P. syringae* flights have also been reported from late April to late July in Maryland (Neal and Eichlin 1983), late April to early July in Kentucky (Potter and Timmons 1983c), and late April to early June in Mississippi (Solomon 1983).

Synanthedon exitiosa generally did not emerge until mid to late May but remained active longer than *P. syringae* with the last captures in mid-October (Fig. 1). During both years in the urban habitats, *S. exitiosa* was first captured on 12 May 2000 and 16 May 2001 (Fig. 6, 7). Peak emergence at all five sites occurred the third week of August 2000 and ranged from 12 to 24 August 2001. Although densities were low, *S. exitiosa* continued to be active until traps were removed on 13 October 2000 and 12 October 2001. In the forest habitats, *S. exitiosa* was first collected in late May during both years (Fig. 8, 9). Peak emergence ranged from 5 to 12 July 2000 and 11 to 19 July 2001. Adult moths were collected until late September both years. A previous study in Tennessee showed an emergence of *S. exitiosa* from late June to early September (Butler 1931, 1932); however, this study was based on daily observations and did not benefit from the

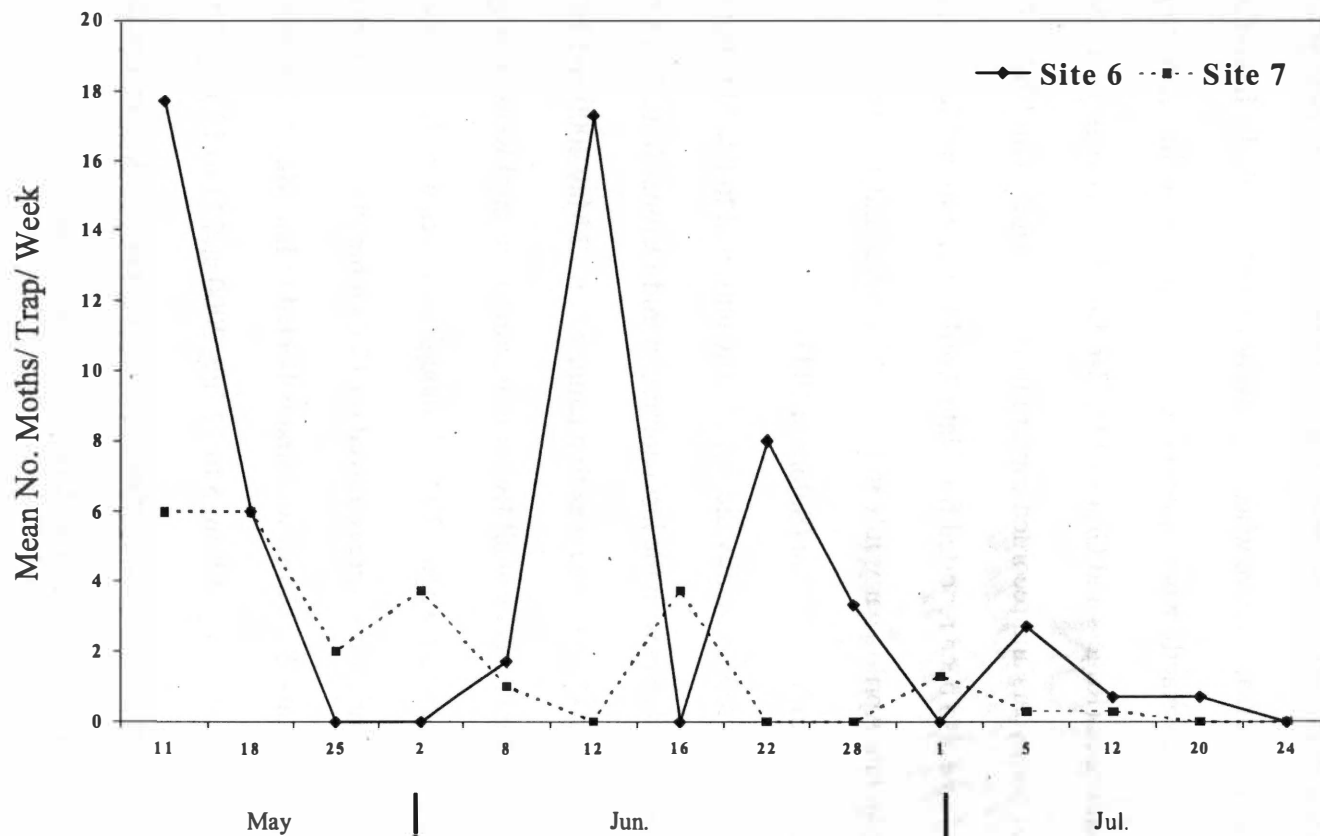


Fig. 4. Seasonal incidence of lilac borer, *Podosesia syringae*, at selected sites in the Great Smoky Mountains National Park, 2000 (*P. syringae* were not collected after 20 July 2000).

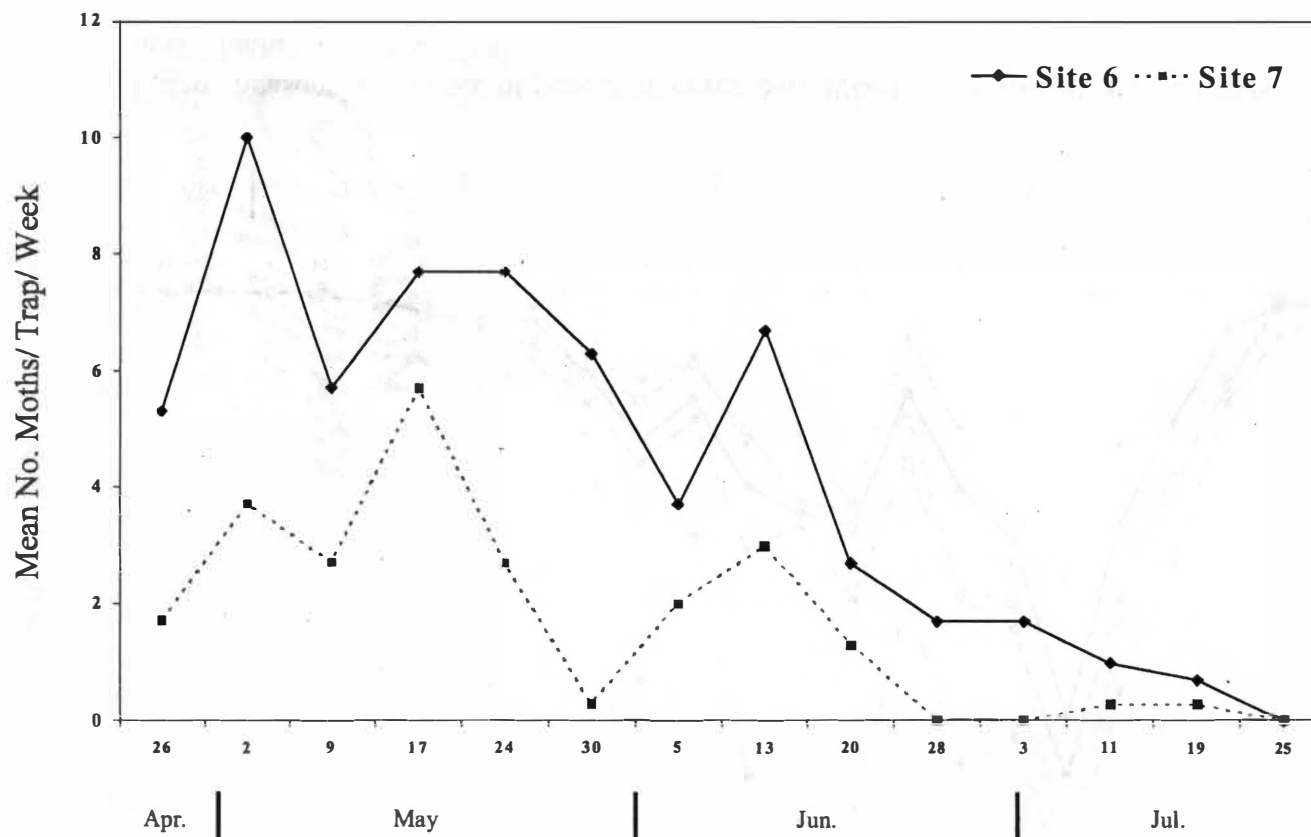


Fig. 5. Seasonal incidence of lilac borer, *Podosesia syringae*, at selected sites in the Great Smoky Mountains National Park, 2001 (*P. syringae* were not collected after 19 July 2001).

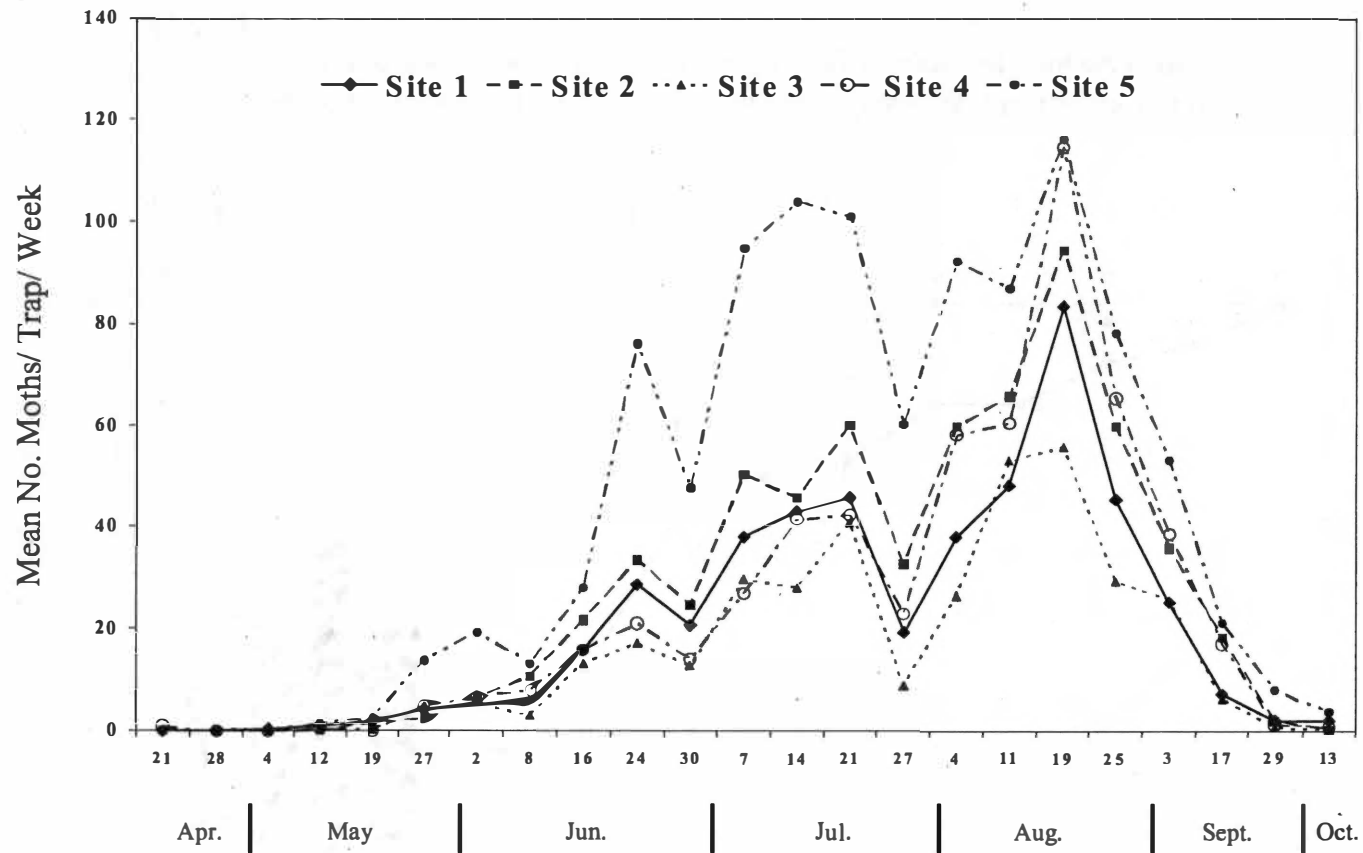


Fig. 6. Seasonal incidence of peachtree borer, *Synanthedon exitiosa*, at selected sites near Chattanooga, TN, 2000.

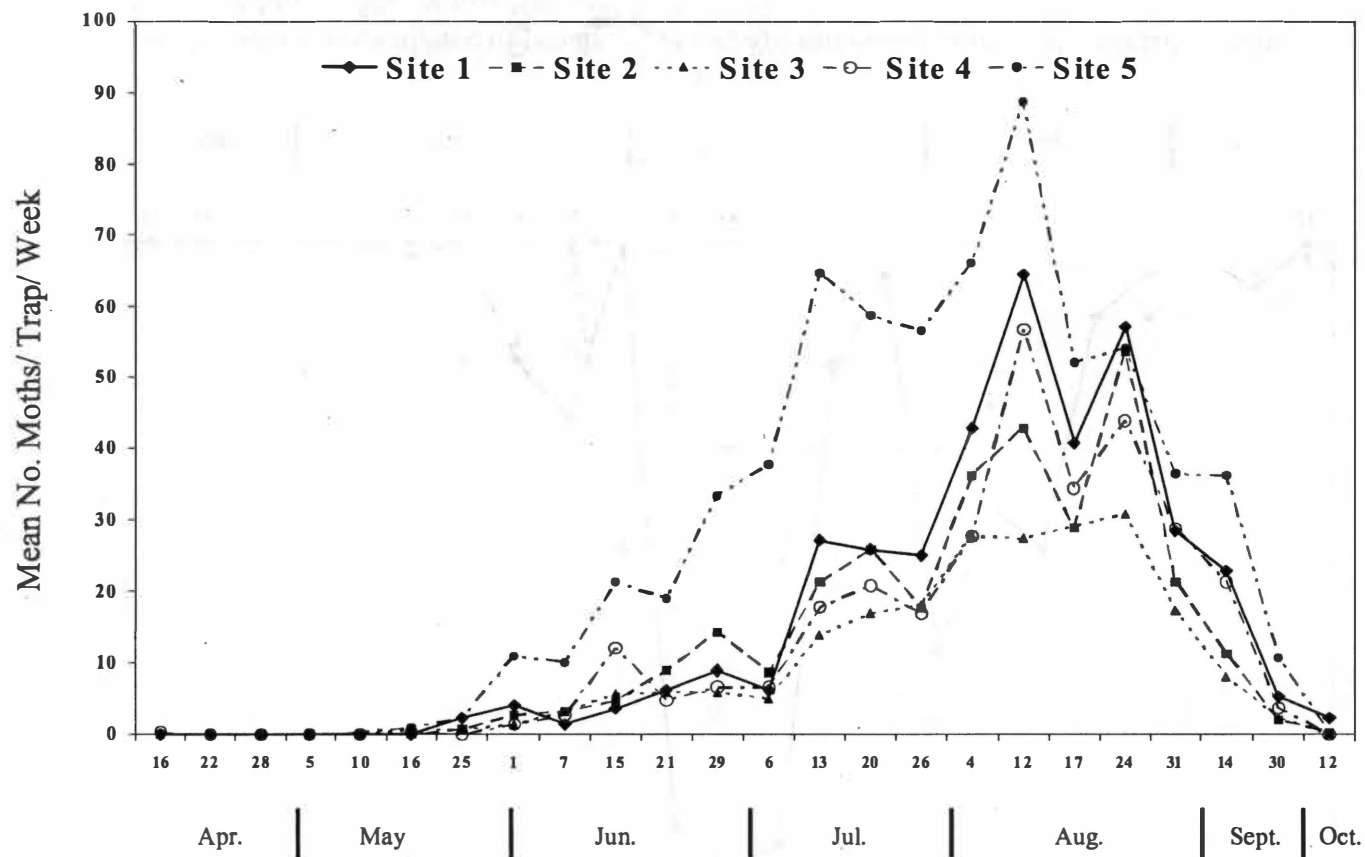


Fig. 7. Seasonal incidence of peachtree borer, *Synanthedon exitiosa*, at selected sites near Chattanooga, TN, 2001.

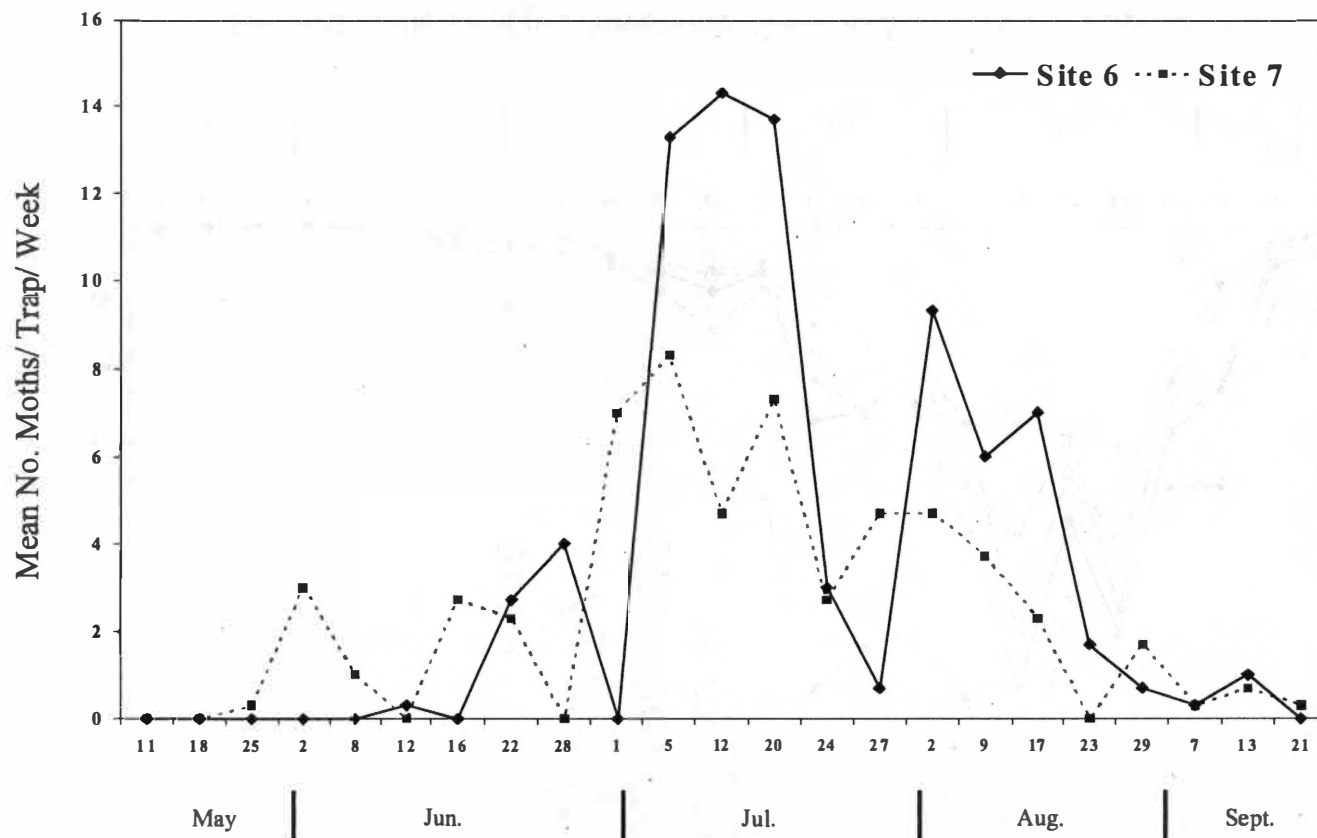


Fig. 8. Seasonal incidence of peachtree borer, *Synanthedon exitiosa*, at selected sites in the Great Smoky Mountains National Park, 2000.

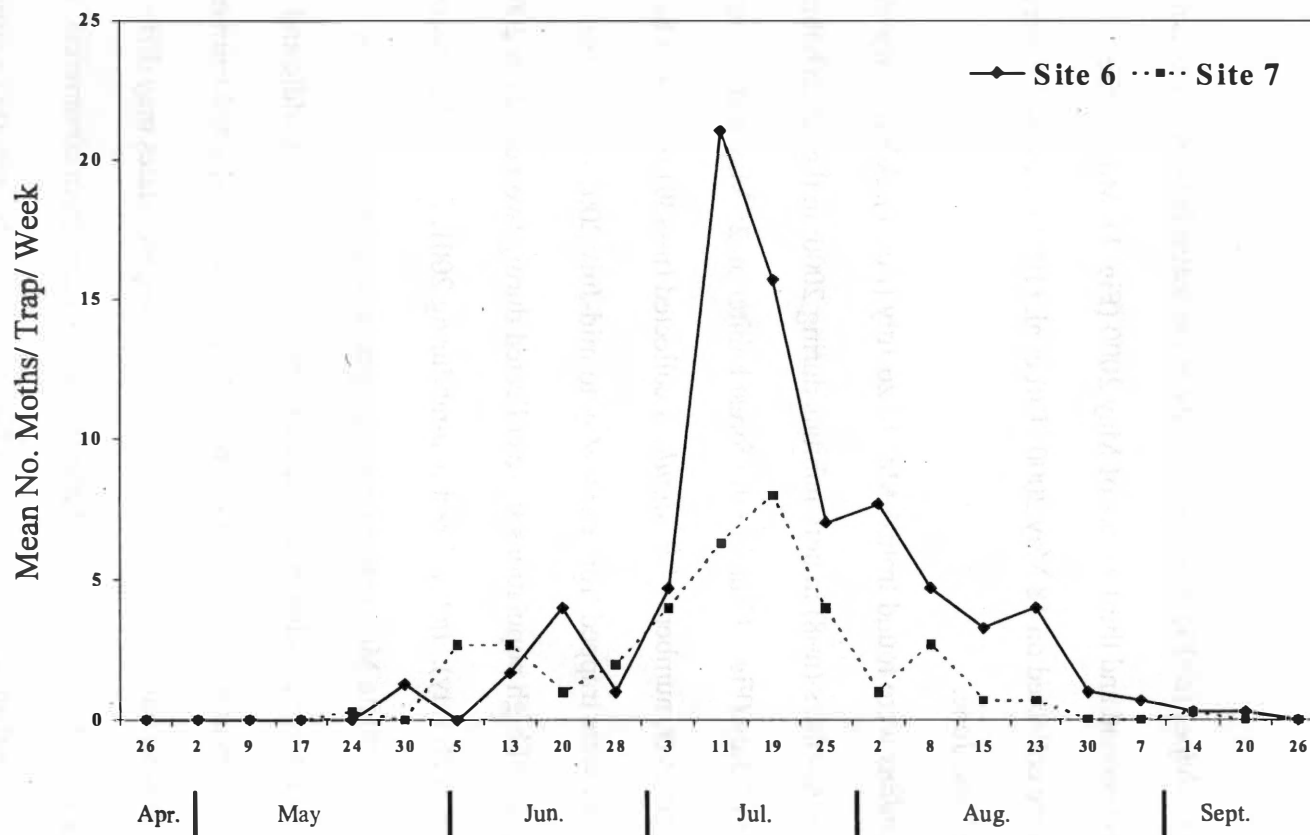


Fig. 9. Seasonal incidence of peachtree borer, *Synanthedon exitiosa*, at selected sites in the Great Smoky Mountains National Park, 2001.

use of pheromones. Research by Rogers and Grant (1991) found *S. exitiosa* from late May to mid-September in urban and nursery habitats, with a peak emergence in late August in both habitats. In South Carolina, *S. exitiosa* was found from mid-May to late October (Gentry et al. 1978) and in Georgia from late April to late October (Yonce and Pate 1979).

Synanthedon fulvipes (n=13) was trapped only at the forest habitat in eastern Tennessee during the second and third weeks of May 2000 (Fig. 1). Most of the individuals (n=6) were collected on 18 May 2000. Taft et al. (1991) records this species as active in late May and June.

Adult *P. simulans* were found from 5 May to 26 July (Fig. 1). Adult *P. simulans* were collected in low numbers (n=8) in both habitats during 2000: in the urban habitat on 12 May, 19 May, and 7 July (Fig. 10) and in the forest habitat on 25 May and 12 June (Fig. 11). In 2001, however, numbers of *P. simulans* collected (n=339) from both habitats increased. *P. simulans* were trapped from early May to mid-July 2001 in the urban habitat (Fig. 12). Peaks of high populations were collected during two periods in 2001, (10 May and 29 June to 20 July). In the forest habitat during 2001, *P. simulans* were collected from mid-May to late May with a peak emergence ranging from 20 June to 19 July (Fig. 13). These findings are almost identical to a previous study in middle and eastern Tennessee (Rogers and Grant 1991) when *P. simulans* were collected from early May to mid-July with peak emergence in late July. Peak emergence dates may differ because the majority of sampling sites in the previous study came from commercial and forest habitats instead of urban habitats. Neal and Eichlin (1983) also reported a similar

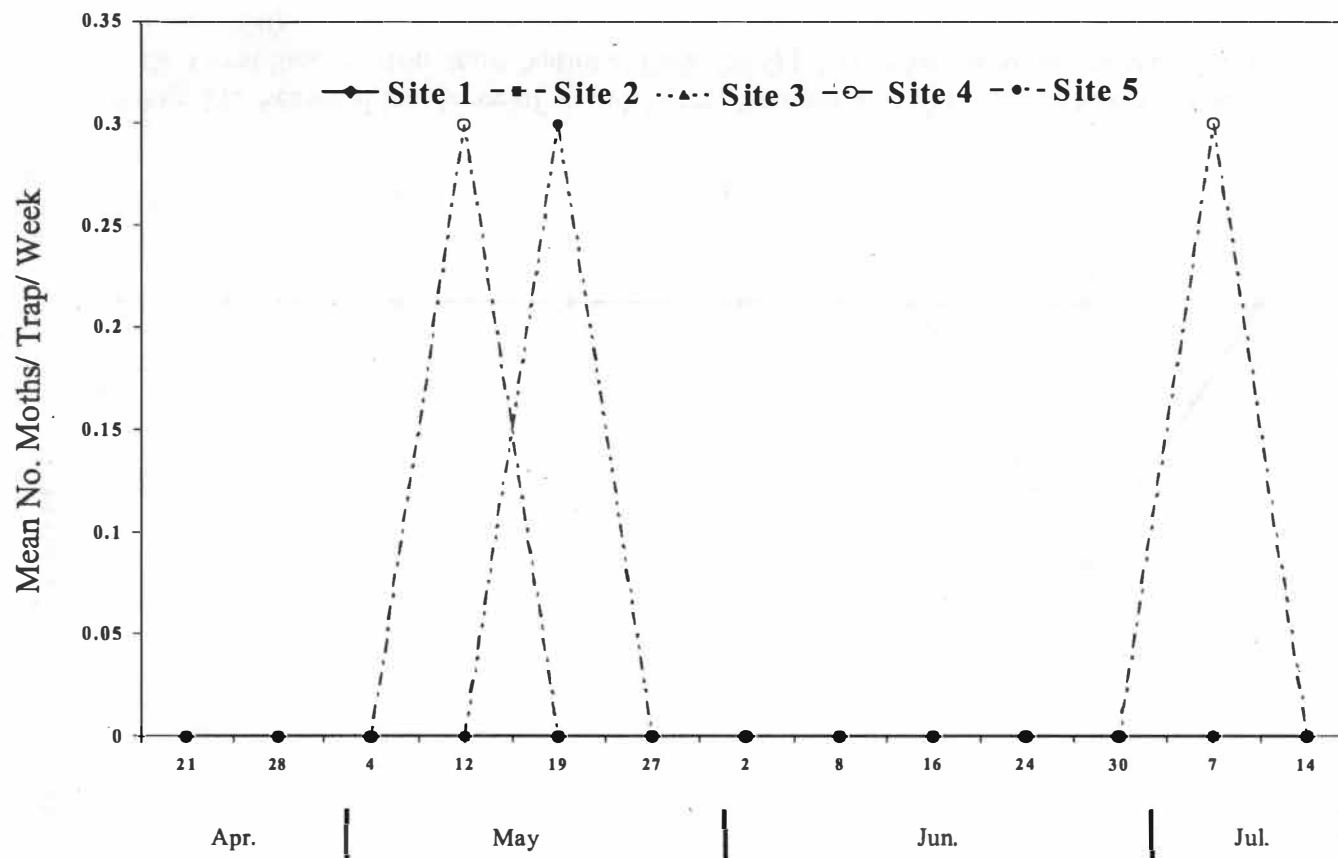


Fig. 10. Seasonal incidence of an oak borer, *Paranthrene simulans*, at selected sites near Chattanooga, TN, 2000 (*P. simulans* were not collected after 14 July 2000).

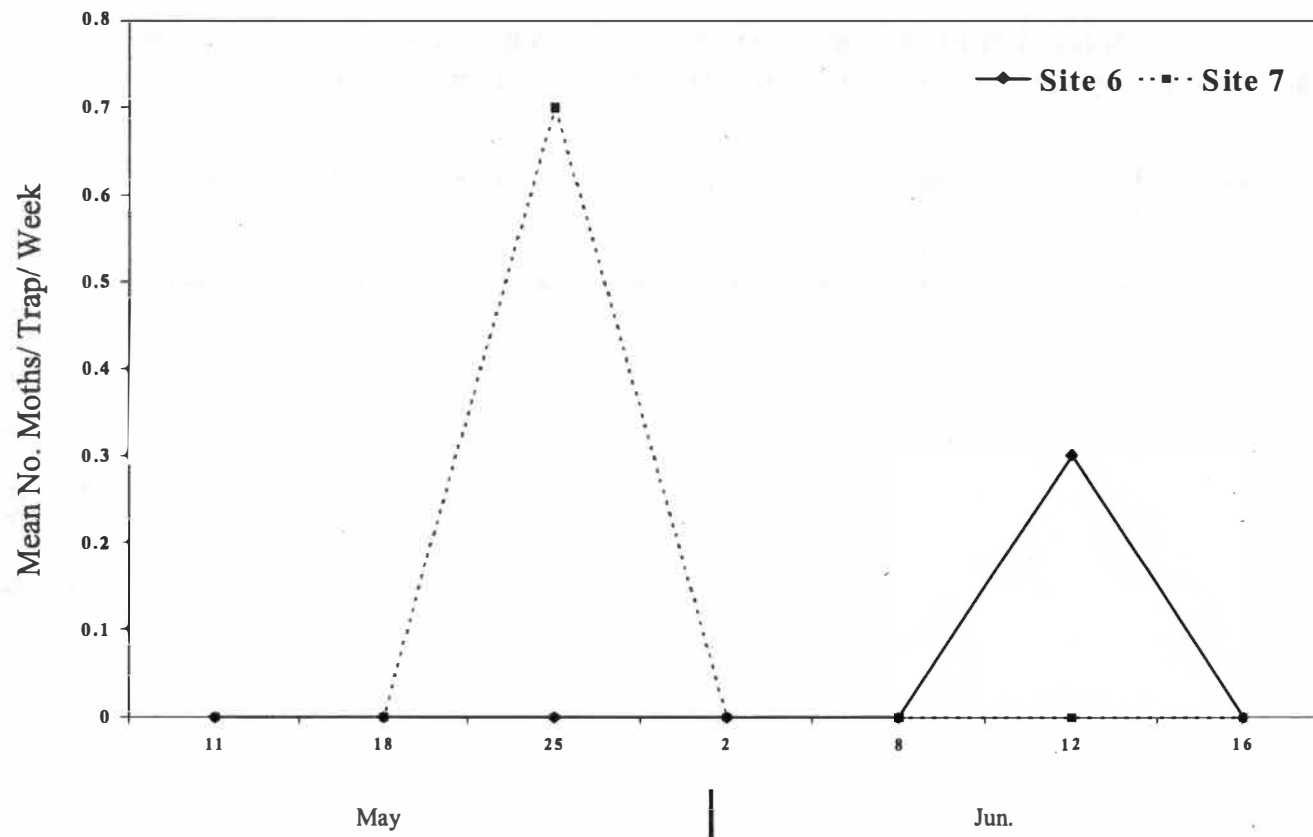


Fig. 11. Seasonal incidence of an oak borer, *Paranthrene simulans*, at selected sites in the Great Smoky Mountains National Park, 2000 (*P. simulans* were not collected after 16 June 2000).

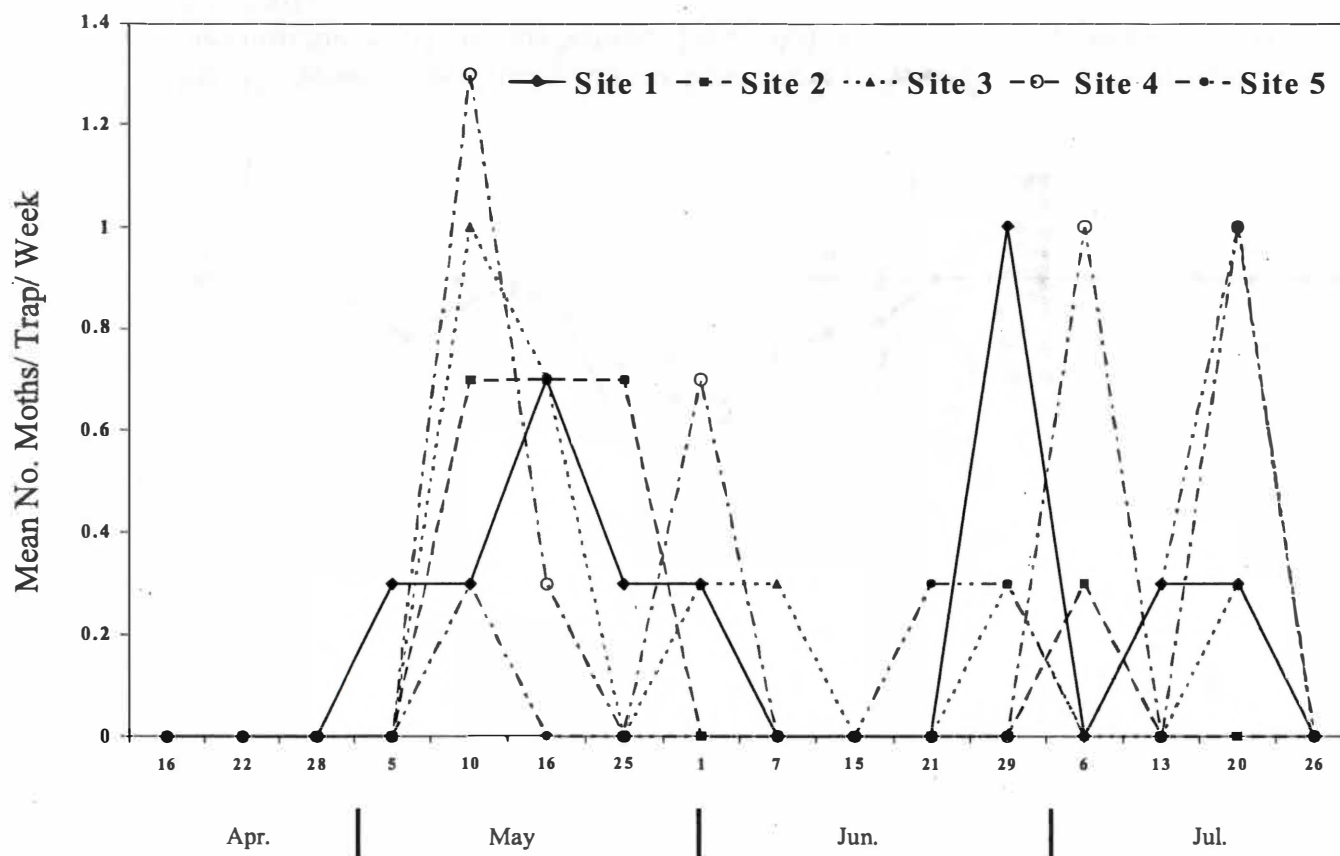


Fig. 12. Seasonal incidence of an oak borer, *Paranthrene simulans*, at selected sites near Chattanooga, TN, 2001 (*P. simulans* were not collected after 20 July 2001).

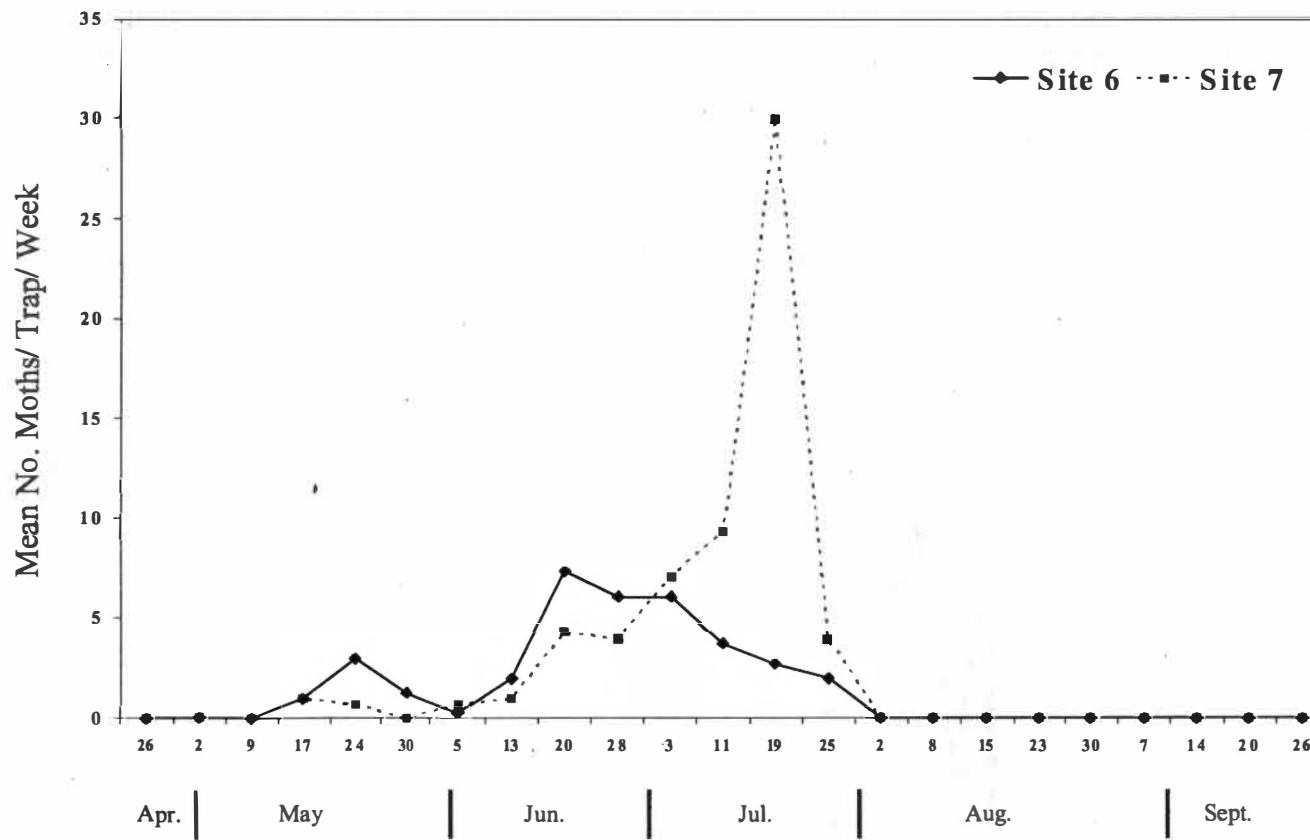


Fig. 13. Seasonal incidence of an oak borer, *Paranthrene simulans*, at selected sites in the Great Smoky Mountains National Park, 2001 (*P. simulans* were not collected after 25 July 2001).

flight period in Maryland that occurred from late May to mid-July with a peak in mid-June. *Synanthedon rhododendri* were collected in the urban habitat from mid-May to late June 2000 and from late May to late July 2001 (Fig. 1). Peak emergence occurred both years from early to mid-June. In the forest habitat, adult *S. rhododendri* (n=3) were collected on only two sampling dates during 2000, 16 June and 12 July. These collection dates agree with data from Maryland (Neal and Eichlin 1983) where six-week flight duration was documented from the last week of May to the first week of July.

Synanthedon fatifera were collected from the urban habitats in low numbers (n=63) during both years with trapping dates from early June to mid-July (Fig. 1). This species was not collected in the forest habitat.

On 16 June 2000, the only specimen of *S. rubrofascia* was collected from the urban habitat (Fig. 1). Although specimens were limited in southeastern Tennessee, Snow et al. (1985) found two generations per year in Georgia with adult males present from April to mid-November peaking in June and September. Because Eichlin and Duckworth (1988) record this species as occurring from Louisiana to Florida and north to Maryland, the single catch in this study may be partially explained by trap location or pheromone type.

Carmenta bassiformis was collected in greater numbers from the forest habitat (n=27) than the urban habitat (n=3). In the forest habitat, *C. bassiformis* were collected both years, from early July to late August 2000 and early June to late August 2001 (Fig. 1). In the urban habitat all three adult *C. bassiformis* were collected on 21 June 2001.

Synanthedon scitula was not collected in any of the forest habitats, and only two specimens were collected in the urban habitat (21 July 2000 and 15 June 2001) (Fig. 1). Only three specimens of *S. kathyae* were collected in the urban habitat (16 June 2000) (Fig. 1). Single specimens of *A. caudata* and *C. ithacae* were collected on 28 June 2000, and on 12 July 2000, respectively, in the forest habitat. Neither species were collected from the urban habitats.

Podosesia aureocincta was trapped from early to mid-July to mid-October during both years in the urban habitats (Fig. 1). These specimens show a longer flight period than the reported three to five weeks in September and October in Maryland (Neal and Eichlin 1983). Only one specimen was trapped in the forest habitat (8 August 2001).

iv. SUMMARY

Thirteen species of clearwing moths were collected during 2000 and 2001 in southeastern Tennessee from urban and forest habitats: lilac borer, banded ash clearwing, peachtree borer, rhododendron borer, black gum borer, dogwood borer, a *Betula* borer, lesser viburnum borer, a holly borer, an oak borer, a borer of ironweed, a borer of *Helenium* and *Heliopsis* spp., and clematis borer. Each species exhibited different emergence times, seasonalities, and peak densities during each season.

Peachtree borer and lilac borer were the two most commonly collected species in both the forest and urban habitats during both years. *P. simulans* was more abundant in

2001 than in 2000, supporting other studies that demonstrate that *P. simulans* has a two-year life cycle with primary emergence in odd-numbered years.

Continued monitoring of clearwing moths in urban and forest habitats can lead to a better understanding of emergence data and species composition which will enable precise timing of insecticides with shorter residual properties or selective activity towards specific growth stages. With a better understanding of which clearwing moth species are likely to occur in localized urban areas, both commercial landscapers and homeowners would have a useful tool when monitoring landscapes for pest damage and when making decisions on appropriate treatments.

CHAPTER III

ELEVATIONAL INFLUENCE ON SPECIES COMPOSITION AND SEASONALITY OF CLEARWING MOTHS IN URBAN LANDSCAPES IN SOUTHEASTERN TENNESSEE

i. INTRODUCTION

Insect phenology is a precise method used to establish accurate timing of insecticide applications. This method considers the growth and development of insects as related to weather conditions, specifically temperature, and the effect is recorded as degree-day units. Essentially, degree-days measure the accumulation of heat units - crucial to insect development - above a minimum temperature level where growth and development can occur for specific insects in a 24-hour period. Because clearwing populations may vary greatly even within a small geographical area from one to another and among varying elevations, it may be necessary to establish degree-day models for individual areas to help better time insecticide treatments (Ascerno 1991).

If data were available that forecast dates when pests have reached vulnerable stages, growers and landscapers would have a valuable tool that would allow for precise timing of insecticides. With precise applications, insecticides with shorter residual properties, lower dosages of material, or with selective activity towards specific growth stages (i.e., egg or first-instar larva) could be included as a key component in an effective integrated pest management program (Herms 1990).

Because little information is available on the influence of elevation on clearwing moth composition and emergence, a two-year study was initiated to monitor these factors among three elevations on Lookout Mountain, Tennessee, and combined elevations of five sites in southeastern Tennessee.

ii. MATERIALS AND METHODS

The influence of elevation on species composition and seasonality of adult clearwing moths was monitored, using pheromone traps, at five urban habitats in Hamilton County, in southeastern Tennessee from April 2000 to October 2001 (Table 1). Specific information about habitat characteristics at each site is provided in the Appendix.

The five sites in the urban habitat were selected based on elevation, the abundance of host plants, and varying degrees of landscape maintenance. Elevations from all five sites were measured using a Garmin Global Positioning System 12 Personal Navigator. Three of the urban sites (Sites 1, 2, and 3) were located on Lookout Mountain, Tennessee. Site 1 was ca. 7.56 km from Site 2 and ca. 9.82 km from Site 3, and Site 2 was ca. 2.25 km from Site 3. Site 1 was located at Reflection Riding Arboretum and Botanical Garden and categorized as a maintained park because grounds crew provided general maintenance (i.e., mowing, pruning, planting new trees and shrubs). Azalea, rhododendron, dogwood, and many other native plant species were abundant. Pheromone traps were spaced from 239 m to 773 m apart. Site 1, labeled a low elevation site, measured 228 m. Site 2 was located in a home landscape and categorized as a maintained

landscape. Azalea and rhododendron dominated the plant species at this site. Pheromone traps were spaced from 29 m to 66 m apart. Site 2, labeled a moderate elevation site, measured 499 m. Site 3 was located at The Commons, a 5.27 ha park owned by the City of Lookout Mountain, and categorized as a maintained park since grounds crew provided general maintenance similar to Site 1. The landscape consists of various native and introduced trees, shrubs, and perennials. Pheromone traps were spaced from 75 m to 171 m apart. Site 3, labeled a high elevation site, measured 651 m, and was the only high elevation site used in this study.

A fourth monitoring site (Site 4) was located on Elder Mountain, Tennessee, and categorized as a maintained landscape. Prior to 1996, this site was a nursery for rhododendrons and azaleas, and as such these two shrubs are prevalent. This site also has an abundance of various oak species. Pheromone traps were spaced from 96 m to 205 m apart. Site 4, labeled a moderate elevation site, measured 553 m. Site 4 was ca. 13.03 km from the closest site on Lookout Mountain (Site 1) and 40.87 km from the fifth site (Site 5) in Hixson, Tennessee.

Site 5, located in a home landscape, was categorized as a maintained landscape. This landscape consisted primarily of rhododendrons and azaleas, but dogwoods, grapevines, and oaks also were prevalent. Pheromone traps were spaced from 57 m to 68 m apart. Site 5, ca. 31.05 km from the closest site on Lookout Mountain (Site 1), was labeled a low elevation site (207 m).

Three pheromone traps were placed at each of the five sites and positioned 60 to 152 cm above the ground surface with similar lighting conditions, primarily diffused

shade. Each pheromone trap consisted of a Biocontrol Services Multipher I bucket trap (Great Lakes IPM, Vestaburg, Michigan) with a white base (203 mm deep by 140 mm wide at the top and 102 mm wide at the bottom) and green cover (267 mm wide). Traps were baited with a lure strip impregnated with 17.4 mg 97/3 z, z-3, 13 C19 acetate/e, e-3, 13 C18 acetate 91% purity (Scentry Biologicals, Billings, Montana). One strip (2.54 x 5.08 cm) of Hercon vapor tape (10% DDVP) was placed at the bottom of each trap to quickly kill and prevent damage to the identification features (e.g., wings, legs, and antennae) of adult moths.

Traps were monitored weekly from mid-April to early September and bimonthly from mid-September to mid-October. On each sampling date, adults were removed from the traps, placed in a labeled Ziploc® bag (900 ml), and taken to the laboratory where they were sorted, processed, and identified to species when possible. Dr. T. D. Eichlin of the California Department of Food and Agriculture Plant Pest Diagnostics Branch in Sacramento, California, and Greg Wiggins and Adriean Mayor, both of the University of Tennessee, assisted with species confirmation and/or identification. Voucher specimens will be incorporated into the University of Tennessee Insect Museum. Traps were baited with a fresh pheromone lure and Hercon vapor tape at the beginning and middle of each trapping year.

Species composition and the influence of elevation on seasonality of the two most abundant species (lilac borer and peachtree borer) were assessed for 2000, 2001, and combined years among: 1) the five combined urban habitat elevations (Low - Sites 1 and 5, Moderate – Sites 2 and 4, and High – Site 3) and 2) the three elevations on Lookout

Mountain (Sites 1 [Low], 2 [Moderate], and 3 [High]). Data were analyzed using SAS (SAS 1999). When significant ($p \leq 0.10$) differences were found among main effects, Tukey's Studentized Range test was used to separate significant differences among treatments/sites.

iii. RESULTS AND DISCUSSION

YEAR 2000

Comparisons Among Combined Elevations

During 2000, 9,784 adult male sesiid moths, representing three genera and nine species, were collected in pheromone-baited traps at five sites, representing three elevational gradients (low, moderate, and high), in southeastern Tennessee (Table 6). The sesiid species trapped included the: lilac borer (also called ash borer), *Podosesia syringae* (Harris), banded ash clearwing, *Podosesia aureocincta* Purrington and Nielsen, peachtree borer, *Synanthedon exitiosa* (Say), rhododendron borer, *S. rhododendri* (Beutenmüller), black gum borer, *S. rubrofascia* (Hy. Edwards), dogwood borer, *S. scitula* (Harris), lesser viburnum borer, *S. fatifera* Hodges, a holly borer, *S. kathyae* Duckworth and Eichlin, and an oak borer, *Paranthrene simulans* (Grote).

Although fewer adult moths were collected at the high elevation ($n=1,189/\text{site}$), this elevation represented the highest in species richness ($n=8$), including *S. scitula* and *S. rubrofascia* which were only collected at the high elevation. The low ($n=2,435.5/\text{site}$) and moderate ($n=1,862/\text{site}$) elevations had the same number of species ($n=6$), but species

Table 6. Species composition of male clearwing moths (Sesiidae) collected in pheromone-baited traps at three elevations among five sites* in southeastern Tennessee during 2000 and 2001.

Species/ Common Name	Low				Moderate				High				Two-Year Totals			
	2000		2001		2000		2001		2000		2001		2000		2001	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
<i>Synanthedon exitiosa</i> , Peachtree Borer	2,251	92.42	1,601	86.26	1,779	95.55	915	88.07	1,081	90.92	660	77.74	5,111	93.16	3,176	84.83
<i>Podosesia syringae</i> , Lilac Borer	176.5	7.25	226.5	12.20	74	3.98	102	9.82	63	5.30	123	14.50	313.5	5.71	451.5	12.05
<i>Podosesia aureocincta</i> , Banded Ash Clearwing	5.5	0.23	18.5	1.00	1	0.05	7	0.67	1	0.09	3	0.35	7.5	0.13	28.5	0.76
<i>Synanthedon fatifera</i> , Lesser Viburnum Borer	0	0.00	0.5	0.03	1	0.05	3	0.29	25	2.10	29	3.41	26	0.47	32.5	0.87
<i>Synanthedon rhododendri</i> , Rhododendron Borer	1	0.04	0.5	0.03	6	0.32	2	0.19	16	1.35	21	2.47	23	0.42	23.5	0.63
<i>Paranthrene simulans</i> , No Common Name	0.5	0.02	9	0.48	1	0.05	10	0.96	0	0.00	9	1.06	1.5	0.03	28	0.75
<i>Carmenta bassiformis</i> , No Common Name	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.35	0	0.00	3	0.08
<i>Synanthedon kathyae</i> , No Common Name	1	0.04	0	0.00	0	0.00	0	0.00	1	0.08	0	0.00	2	0.04	0	0.00
<i>Synanthedon scitula</i> , Dogwood Borer	0	0.00	0	0.00	0	0.00	0	0.00	1	0.08	1	0.12	1	0.02	1	0.03
<i>Synanthedon rubrofascia</i> , Black Gum Borer	0	0.00	0	0.00	0	0.00	0	0.00	1	0.08	0	0.00	1	0.02	0	0.00
TOTALS	2,435.5	100	1,856	100	1,862	100	1,039	100	1,189	100	849	100	5,486.5	100	3,744	100

* Values represent average total numbers of moths/three traps/year (two sites each at low and moderate elevations; one site at the high elevation).

composition differed slightly. Specifically, *S. kathyae* was collected at the low elevation but not at the moderate elevation sites, and *S. fatifera* was collected at the moderate elevation but not at the low elevation site. Densities of rhododendron borer were 8.0x and 1.3x greater at the high elevation when compared to the low and moderate elevations, respectively. These differences occurred even though host plant abundance was lower at the high elevation when compared to the low and moderate elevation. However, since rhododendron borer was collected in low numbers (n=30) in 2000, additional data may be needed to provide further evidence that elevation may be a factor in densities of rhododendron borer.

The peachtree borer was collected more than any other species (n=9,141) and represented ca. 93% of all adults collected during 2000. Peachtree borers comprised the majority of specimens collected at each elevation (2,251, 1,779, and 1,081 moths/three traps/site at the low, moderate, and high elevations, respectively). Thus, elevation significantly influenced densities of adult peachtree borers ($r^2 = 0.81$; $F = 28.85$; $df = 2$, 269; $p < 0.0001$) during 2000 (Table 7). Densities of peachtree borers decreased significantly as elevation increased. Densities of male peachtree borers were about 2.1x and 1.6x greater at the low and moderate elevations, respectively, compared to the high elevation (32.62 [low], 25.97 [moderate], and 15.67 [high] adults/three traps/week) (Fig. 14). The differences in density levels are likely attributed to a change in temperature between the low and high elevation. Cooler temperatures at the high elevation may shorten flight periods of peachtree borer adults thus reducing abundance. Other factors,

Table 7. Influence of elevation on densities of lilac borer, *Podosesia syringae*, and peachtree borer, *Synanthedon exitiosa*, in southeastern Tennessee during 2000 and 2001.

Elevation	2000		2001		Both Years	
	Lilac Borer	Peachtree Borer	Lilac Borer	Peachtree Borer	Lilac Borer	Peachtree Borer
Low	2.56 ± 5.97* a [†]	32.62 ± 35.50 a	3.15 ± 6.52 a	22.24 ± 27.52 a	2.86 ± 6.25 a	27.32 ± 32.04 a
Moderate	1.08 ± 2.06 b	25.97 ± 29.23 b	1.42 ± 3.50 a	12.71 ± 17.73 ab	1.25 ± 2.89 b	19.17 ± 24.89 b
High	0.91 ± 1.87 b	15.67 ± 18.59 c	1.71 ± 3.30 a	9.17 ± 11.36 bc	1.32 ± 2.72 b	12.35 ± 15.62 b

* Values represent average number of moths/three traps/week (two sites each at low and moderate elevations; one site at the high elevation).

[†] Values within a column followed by the same letter are not significantly different (P>0.05) (Tukey's Studentized Range test).

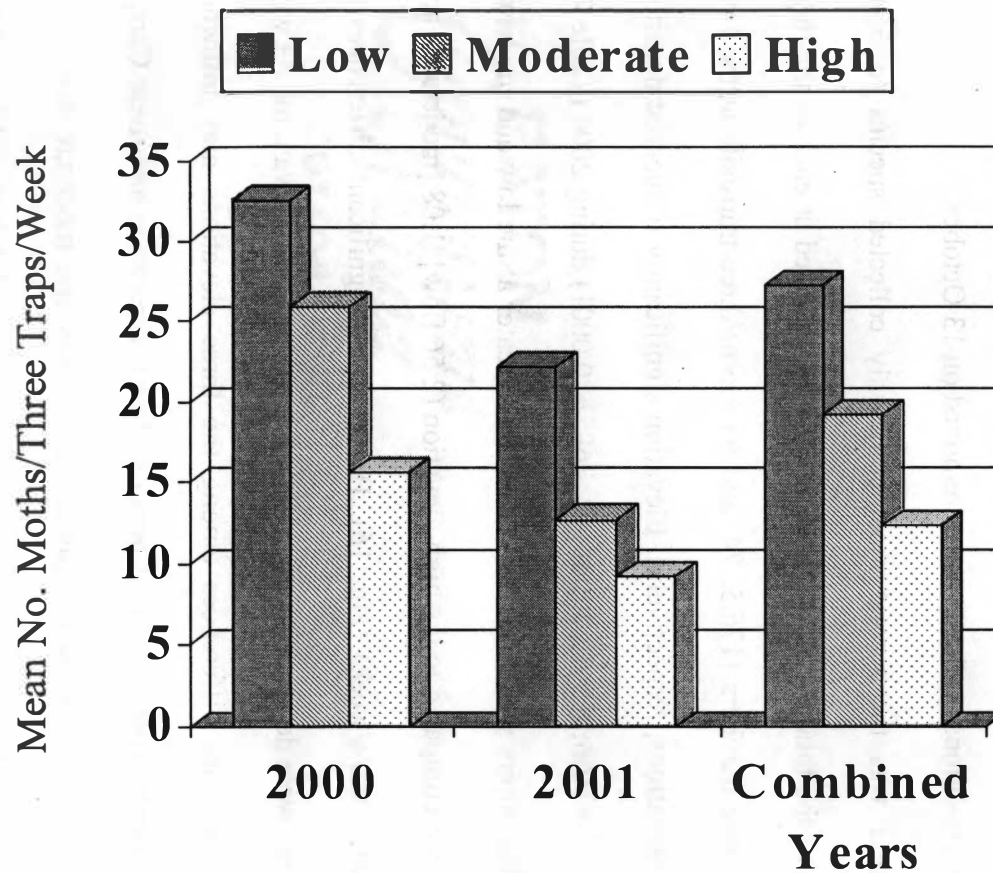


Fig. 14. Influence of elevation on mean numbers of peachtree borer, *Synanthedon exitiosa*, collected weekly in southeastern Tennessee, 2000 and 2001.

including host plant abundance and susceptibility and attractiveness of the pheromone used in this study, may have resulted in differences of peachtree borer densities.

Peachtree borer adult males were first collected on 12 May at the low elevation, two weeks earlier than at the moderate and high elevational sites, which occurred on 27 May (Fig. 15). Densities peaked on 19 August at all three elevations; however, a smaller and earlier peak was noted on 14 July at the low elevation and one week later (21 July) at the remaining two elevations. Although densities were low (< 5 /three traps/week), flights continued at all three elevations until traps were removed on 13 October.

The lilac borer was the second most commonly collected species ($n=564$), representing ca. 6% of the total (Table 6). Lilac borer was collected at each of the three elevations in measurable numbers (176.5, 74, and 63 moths/three traps/site at the low, moderate, and high elevations, respectively). Elevation significantly influenced densities of adult lilac borers ($r^2 = 0.66$; $F = 13.29$; $df = 2, 269$; $p < 0.0001$) during 2000 (Table 7). Densities of male lilac borers were about 2.4x and 2.8x greater at the low and moderate elevations, respectively, compared to the high elevation (2.56 [low], 1.08 [moderate], and 0.91 [high] adults/three traps/week) (Fig. 16). However, no significant differences in numbers of lilac borers were detected between the moderate and high elevations. As with peachtree borer, temperature differences among the three elevations may influence abundance of lilac borer by reducing flight periods. Privet, *Ligustrum amurense* Carr, a host plant of the lilac borer, was more abundant at the low and moderate sites when compared to the high site and may also explain the differences in densities of lilac borer

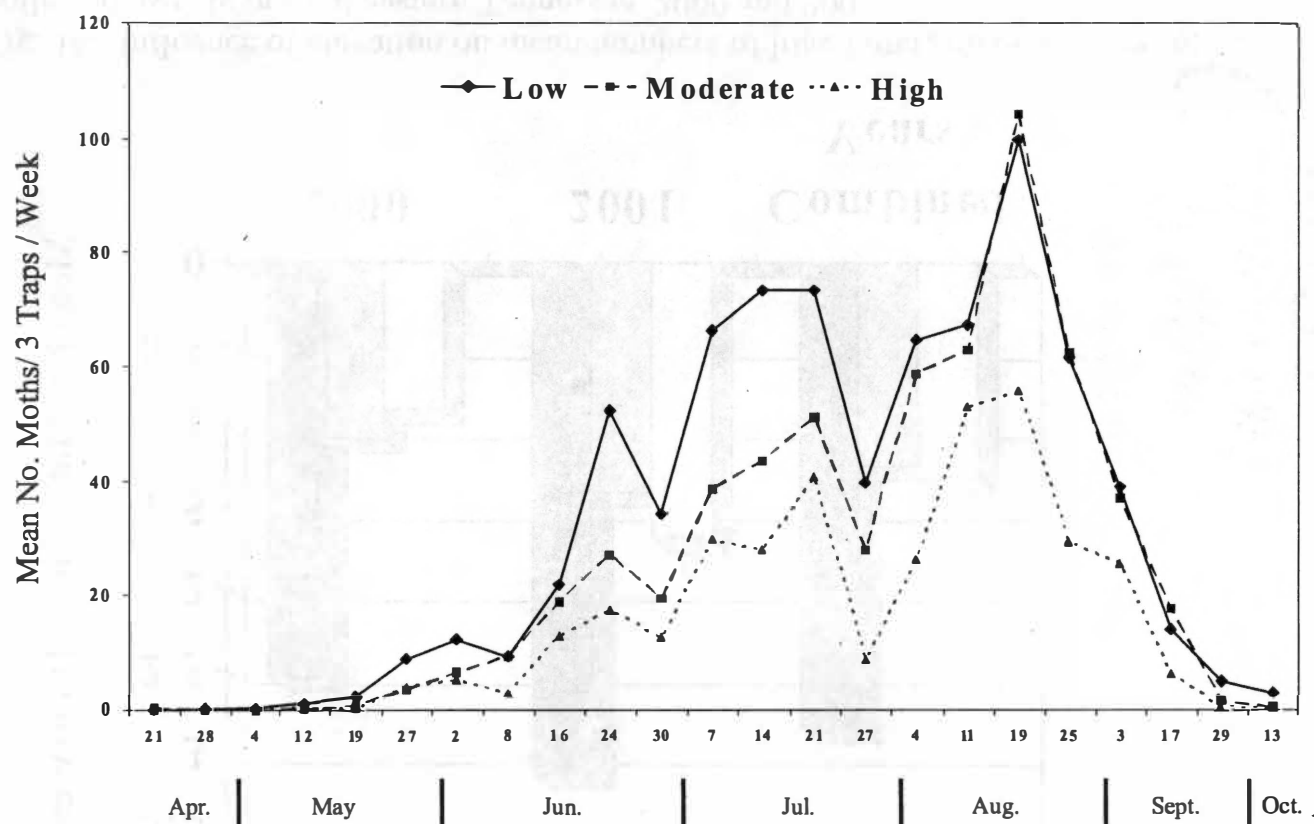


Fig. 15. Influence of elevation on seasonality of peachtree borer, *Synanthedon exitiosa*, at selected sites in southeastern Tennessee, 2000.

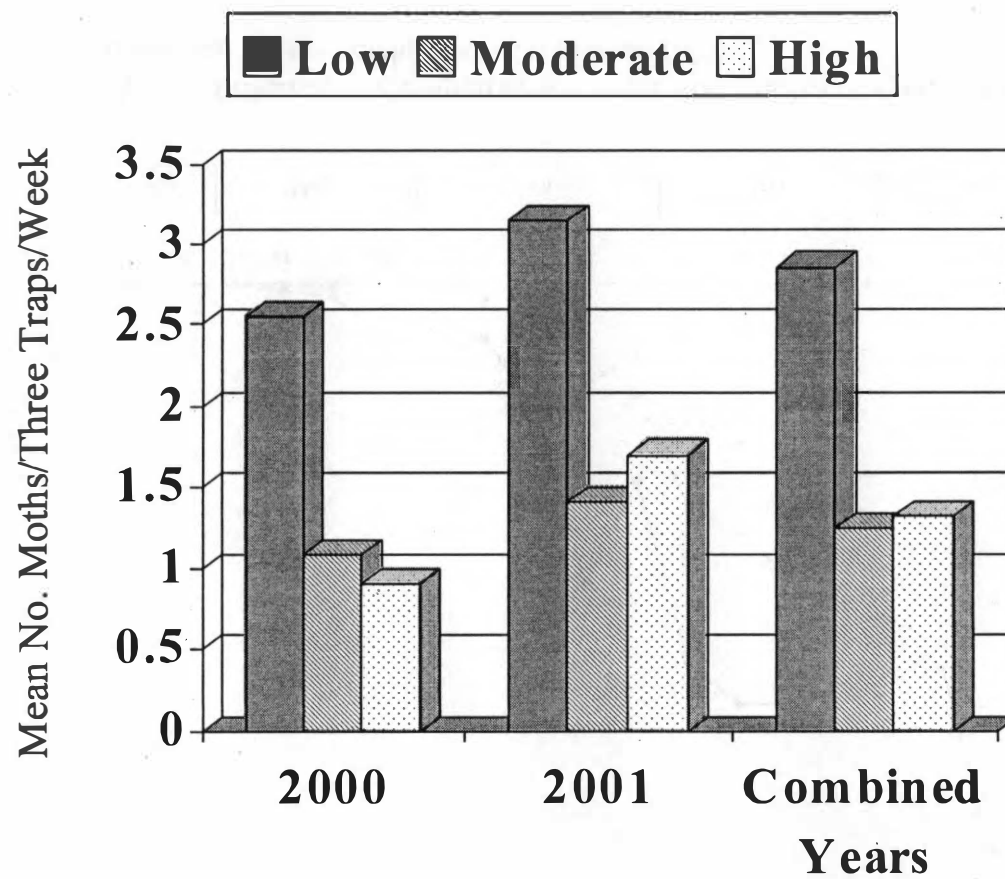


Fig. 16. Influence of elevation on mean numbers of lilac borer, *Podosesia syringae*, collected weekly in southeastern Tennessee, 2000 and 2001.

(Appendix). Although this pheromone collected lilac borers, greater numbers may have been collected using a different pheromone.

Lilac borer was active at all three elevations from the first day (21 April) traps were monitored until early to late July (Fig. 17). On 21 April, densities of adults collected were 6.0x and 10.6x greater at the low elevation than at the moderate and high elevations, respectively. Weekly trap captures were generally much greater at the low elevation sites than at the moderate or high elevations throughout April to mid-May. The highest peak for the low elevation occurred on the first collection date, on 21 April; however, a smaller peak occurred two weeks later on 4 May. Peaks at the moderate and high elevations occurred between 19 and 27 May, five weeks later than the first peak at the low elevation. When adult male populations peaked at the moderate and high elevations, the population at the low elevation was rapidly declining, and the numbers of specimens collected were lower than the numbers of specimens that comprised the moderate and high peaks. This result is likely caused by an increase in temperature at the low site which may limit lilac borer emergence. Lilac borer was not collected after 21 July at any of the three elevations.

The remaining seven species were collected in low numbers and collectively comprised only ca. 1% (n=79) of all specimens collected (Table 6). Two species, *S. rhododendron* (n=30) and *S. fatifera* (n=27) were the most abundant of these seven species. Only one specimen of *S. scitula* and *S. rubrofascia* were collected in 2000.

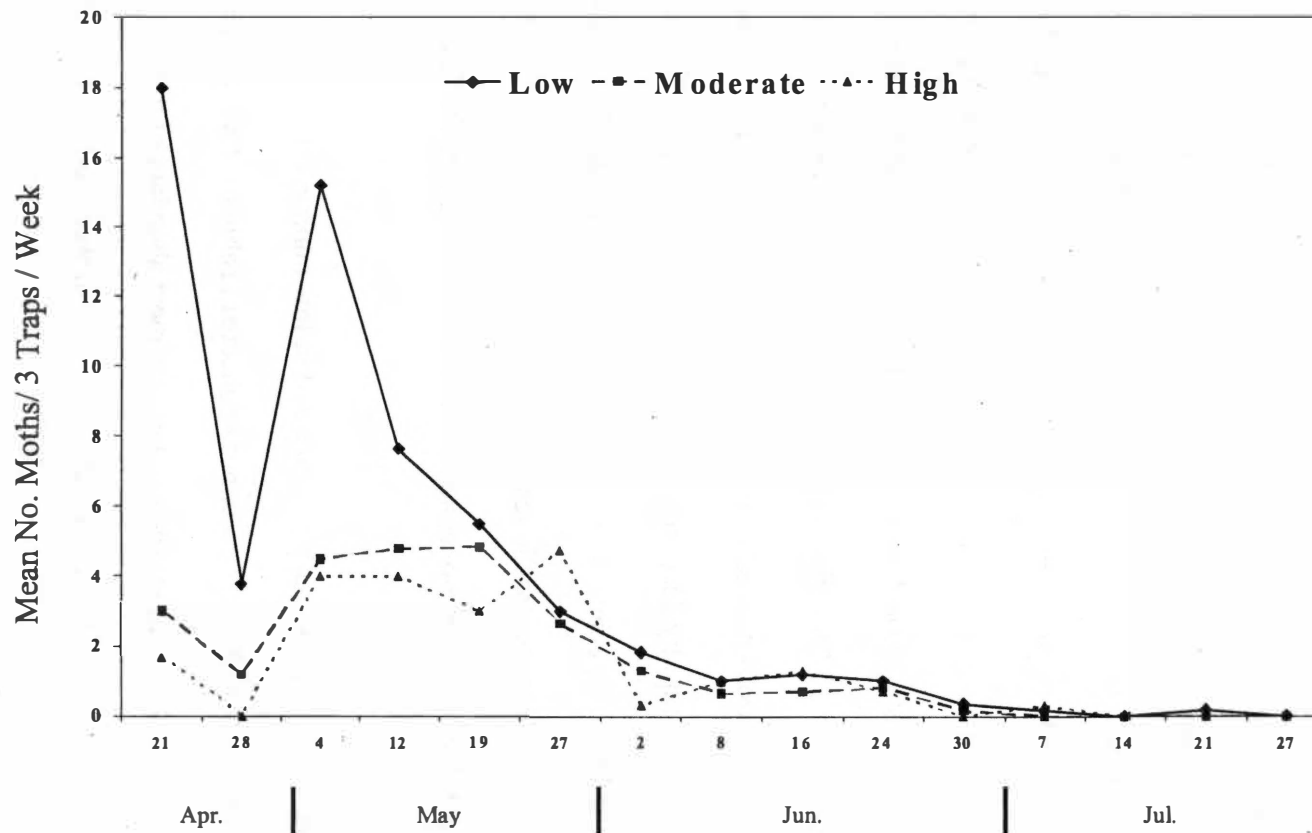


Fig. 17. Influence of elevation on seasonality of lilac borer, *Podosesia syringae*, at selected sites in southeastern Tennessee, 2000 (*P. syringae* were not collected after 21 July 2000).

Comparisons Among Three Elevations at Lookout Mountain

Species composition was also assessed for the low, moderate, and high elevational sites on Lookout Mountain separately during 2000 because of their proximity to each other and similar site characteristics (Table 1). Pheromone-baited traps, among the three elevations, collected 4,791 adult male sesiid moths, representing eight species in only two genera (*Synanthedon* and *Podosesia*) (Table 8). The sesiid species trapped included the: lilac borer, banded ash clearwing, peachtree borer, rhododendron borer, dogwood borer, lesser viburnum borer, *S. kathyae*, and *S. rubrofascia*. Frequency of sessid species trapped may be due to population densities of each species, attractiveness to the pheromone, and environmental and site factors such as temperature, wetness (i.e., dew, fog, and rain), and host density and health.

The moderate site was the least diverse site on Lookout Mountain, with only four species (i.e., peachtree borer, lilac borer, banded ash clearwing, and rhododendron borer) collected. This site also had the most clearwing adults collected (n=1,958), primarily due to the large number (n=1,876) of peachtree borers. *S. fatifera* was not collected at the low or moderate elevations but was relatively abundant (n=25) at the highest elevation. As was observed when all five sites were combined, densities of rhododendron borer were about 8.0x and 2.0x greater at the high elevation site when compared to the low and moderate elevations, respectively, on Lookout Mountain. *Paranthrene simulans* and *C. bassiformis* were not found at any of the three elevations while *S. scitula* and *S. rubrofascia* were only found at the high elevation on Lookout Mountain in 2000.

Table 8. Species composition of male clearwing moths (Sesiidae) collected in pheromone-baited traps at three elevations on Lookout Mountain in southeastern Tennessee during 2000 and 2001.

Species/ Common Name	Site 1 (Low)				Site 2 (Moderate)				Site 3 (High)				Two-Year Totals			
	2000		2001		2000		2001		2000		2001		2000		2001	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
<i>Synanthedon exitiosa</i> , Peachtree Borer	1,441	87.65	1,122	77.81	1,876	95.81	912	91.02	1,081	90.92	660	77.74	4,398	91.80	2,694	81.81
<i>Podotesia syringae</i> , Lilac Borer	191	11.62	281	19.49	72	3.68	76	7.58	63	5.30	123	14.50	326	6.81	480	14.58
<i>Podotesia aureocincta</i> , Banded Ash Clearwing	8	0.49	26	1.80	2	0.10	1	0.10	1	0.09	3	0.35	11	0.23	30	0.91
<i>Synanthedon fatifera</i> , Lesser Viburnum Borer	0	0.00	1	0.07	0	0.00	3	0.30	25	2.10	29	3.41	25	0.52	33	1.00
<i>Synanthedon rhododendri</i> , Rhododendron Borer	2	0.12	1	0.07	8	0.41	3	0.30	16	1.35	21	2.47	26	0.54	25	0.76
<i>Paranthrene simulans</i> , No Common Name	0	0.00	11	0.76	0	0.00	7	0.70	0	0.00	9	1.06	0	0.00	27	0.82
<i>Carmenta bassiformis</i> , No Common Name	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.35	0	0.00	3	0.09
<i>Synanthedon kathyae</i> , No Common Name	2	0.12	0	0.00	0	0.00	0	0.00	1	0.08	0	0.00	3	0.06	0	0.00
<i>Synanthedon scitula</i> , Dogwood Borer	0	0.00	0	0.00	0	0.00	0	0.00	1	0.08	1	0.12	1	0.02	1	0.03
<i>Synanthedon rubrofascia</i> , Black Gum Borer	0	0.00	0	0.00	0	0.00	0	0.00	1	0.08	0	0.00	1	0.02	0	0.00
TOTALS	1,644	100	1,442	100	1,958	100	1,002	100	1,189	100	849	100	4,791	100	3,293	100

Peachtree borer was the most commonly collected species at all three sites (1,441 [low], 1,876 [moderate], and 1,081 [high]) and comprised 91.8% of all moths collected at the Lookout Mountain sites (n=4,791). Peachtree borer was collected from the three elevations on Lookout Mountain from 4 May to 13 October 2000 (Fig. 18). Seasonality remained similar among all three elevations peaking on 19 August at all sites. Population densities were generally higher at the moderate elevation when compared to low and high elevations, a trend noted throughout the entire collection period at Lookout Mountain.

The lilac borer was again the second most commonly collected species (n=326), representing 6.8% of the total. Lilac borers were active from the first day traps were collected on 21 April to early July. Densities of lilac borer were ca. 5.7x and 11.0x greater at the low elevation than at the moderate and high elevations, respectively (Fig. 19). The highest peak occurred on the first collection date at the low elevation, although a smaller peak occurred on 4 May. The moderate and high sites peaked on 19 and 27 May, respectively, which was about 4 to 5 weeks after the first peak at the low elevation on Lookout Mountain. Populations of adult male clearwings sharply declined after 27 May, and no males were collected after 21 July 2000.

The remaining six clearwing species were collected in low numbers and collectively comprised only 1.4% (n=67) of all specimens (Table 8). *Synanthedon fatifera* (n=25) and *S. rhododendri* (n=26) were the two most common species of the remaining clearwing males collected from the three elevations on Lookout Mountain. Low numbers of these species may be due to low population densities or attractiveness to the pheromone.

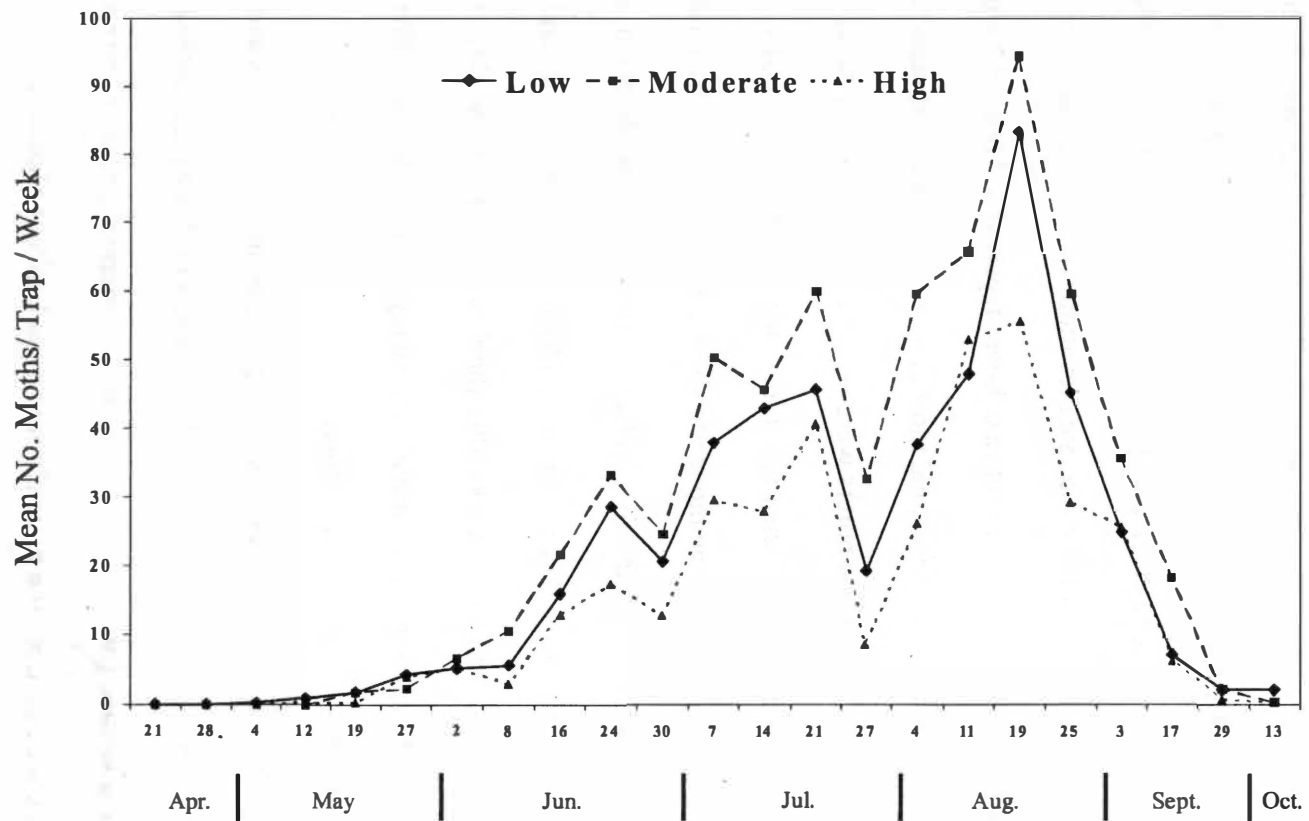


Fig. 18. Influence of elevation on seasonality of peachtree borer, *Synanthedon exitiosa*, at Lookout Mountain, TN, 2000.

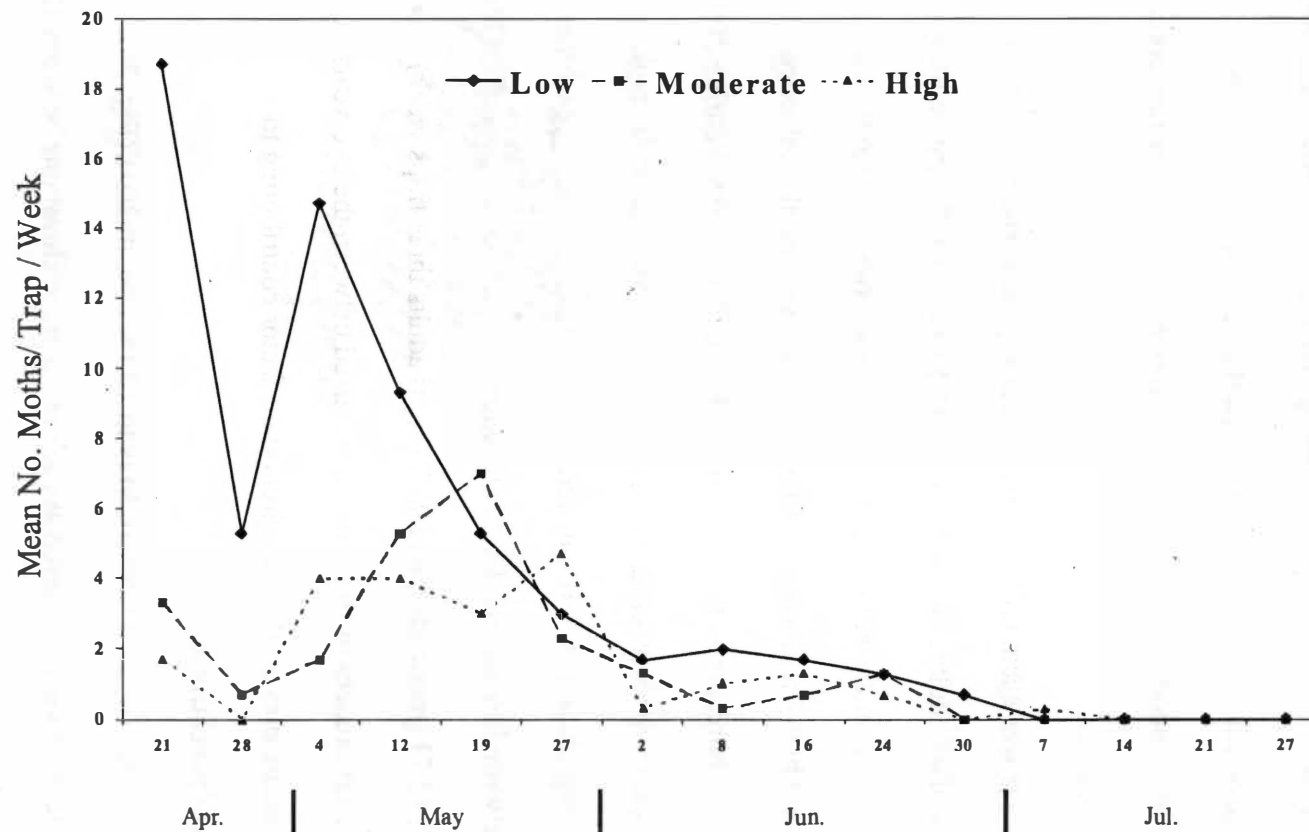


Fig. 19. Influence of elevation on seasonality of lilac borer, *Podosesia syringae*, at Lookout Mountain, TN, 2000 (*P. syringae* were not collected after 21 July 2000).

YEAR 2001

Comparisons Among Combined Elevations

During 2001, 6,639 adult male sesiid moths, representing four genera and eight species, were collected in pheromone-baited traps among five elevations in southeastern Tennessee (Table 6). The sesiid species trapped included the: lilac borer, banded ash clearwing, peachtree borer, rhododendron borer, dogwood borer, lesser viburnum borer, *C. bassiformis*, and *P. simulans*.

The peachtree borer was again collected more than any other species ($n=5,692$) and represented ca. 86% of all adults collected during 2001 (Table 6). Peachtree borers comprised the majority of specimens collected at each elevation (low - $n=1,601$ /site, moderate - $n=915$ /site, and high - $n=660$ /site). Elevation did significantly influence densities of adult peachtree borers ($r^2 = 0.78$; $F = 6.13$; $df = 2, 6$; $p=0.0355$) during 2001, as densities were significantly greater (ca. 2.4x) at the low elevation than at the high elevation (Table 7). No significant ($p>0.05$) differences in densities of adult peachtree borers were detected between low and moderate elevations or between moderate and high elevations (22.24 [low], 12.71 [moderate], and 9.17 [high] adults/three traps/week) (Table 7, Fig. 14). Since differences in significance occurred between the two years, it seems likely that temperature may be the most important factor contributing to differences in densities of peachtree borers.

Peachtree borers were collected from 16 May to 12 October in 2001 (Fig. 20). Peak populations of male clearwings occurred at each of the three elevations between 12-

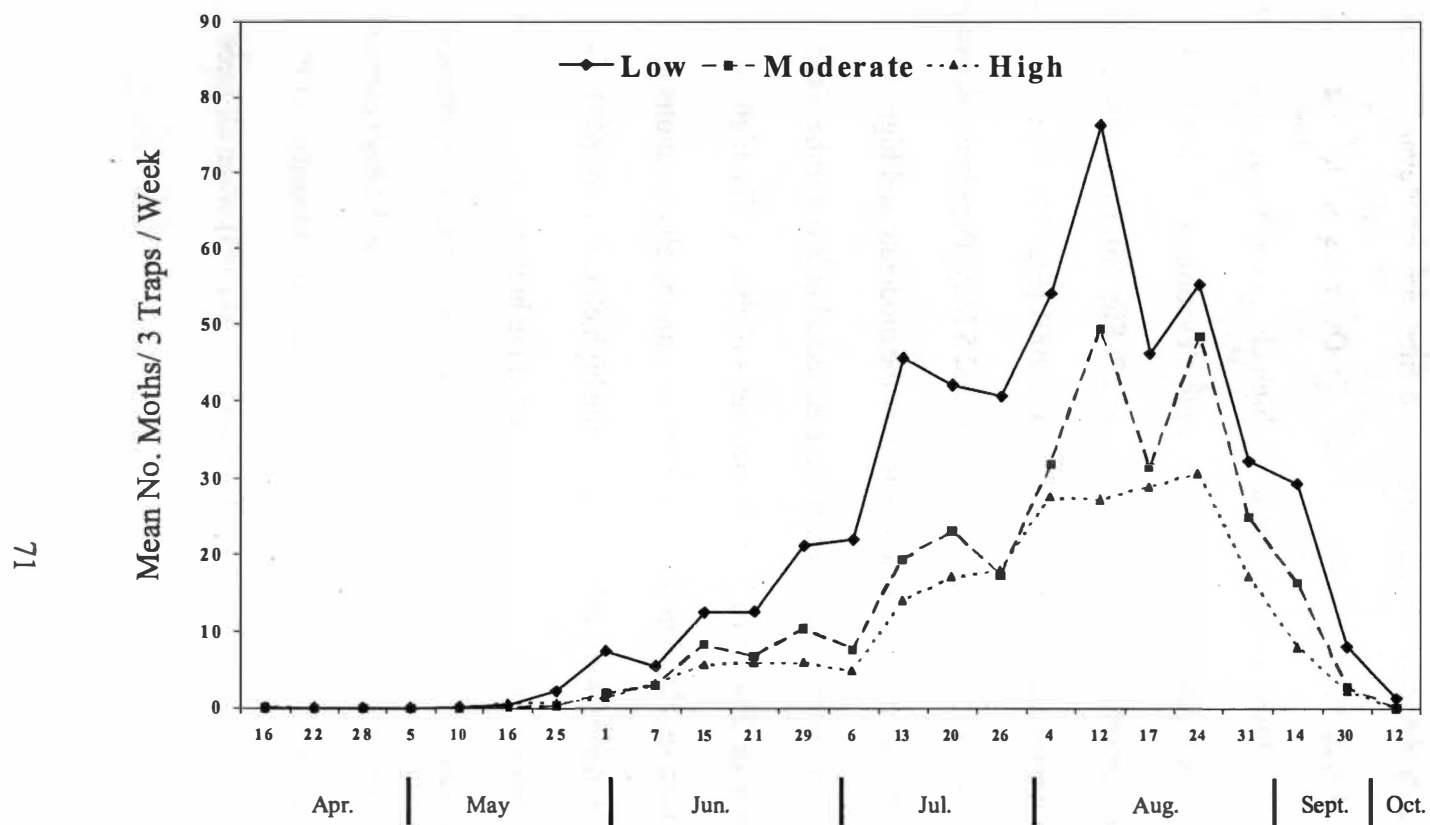


Fig. 20. Influence of elevation on seasonality of peachtree borer, *Synanthedon exitiosa*, at selected sites in southeastern Tennessee, 2001.

24 August. In general, densities of peachtree borer at the low elevation was greater than those of the moderate or high elevation on each sampling date.

The lilac borer was the second most commonly collected species ($n=780$), representing ca. 12% of the total (Table 6). Although densities of lilac borer were numerically different at each elevation no significant differences among elevations were detected ($r^2 = 0.68$; $F = 2.15$; $df = 2, 6$; $p=0.1973$) (Table 7). Densities of lilac borer were about 1.9x greater at the low elevation compared to the high elevation, but densities at the moderate elevation were 1.2x greater than those at the high elevation (3.15 [low], 1.42 [moderate], and 1.71 [high] adults/three traps/week) (Table 7, Fig. 16). Lilac borers were collected from the first trapping date (16 April) until 6 July 2001 (Fig. 21). Peak emergence for each elevation occurred between 28 April and 5 May. Population densities were 24.0x and 28.0x greater at the low elevations than at the moderate and high elevation, respectively. The remaining six species were collected in low numbers and collectively comprised only ca. 2% ($n=167$) of all specimens (Table 6). The high elevation again was the most species rich (eight species) site among all elevations in 2001, although fewer adult moths were collected from the high elevation ($n=849$). Two species, *S. scitula* and *C. bassiformis*, were only collected at the high elevation. The low ($n=1,856$ /site) and moderate ($n=1,039$ /site) elevations had the same number of species ($n=6$). Densities of rhododendron borer were 21.0x and 5.3x greater at the high elevation site when compared to the low and moderate elevations, respectively. Densities of *P. simulans* were also ca. 16.0x greater in 2001 ($n=47$) than in 2000 ($n=3$) when all three elevations are combined.

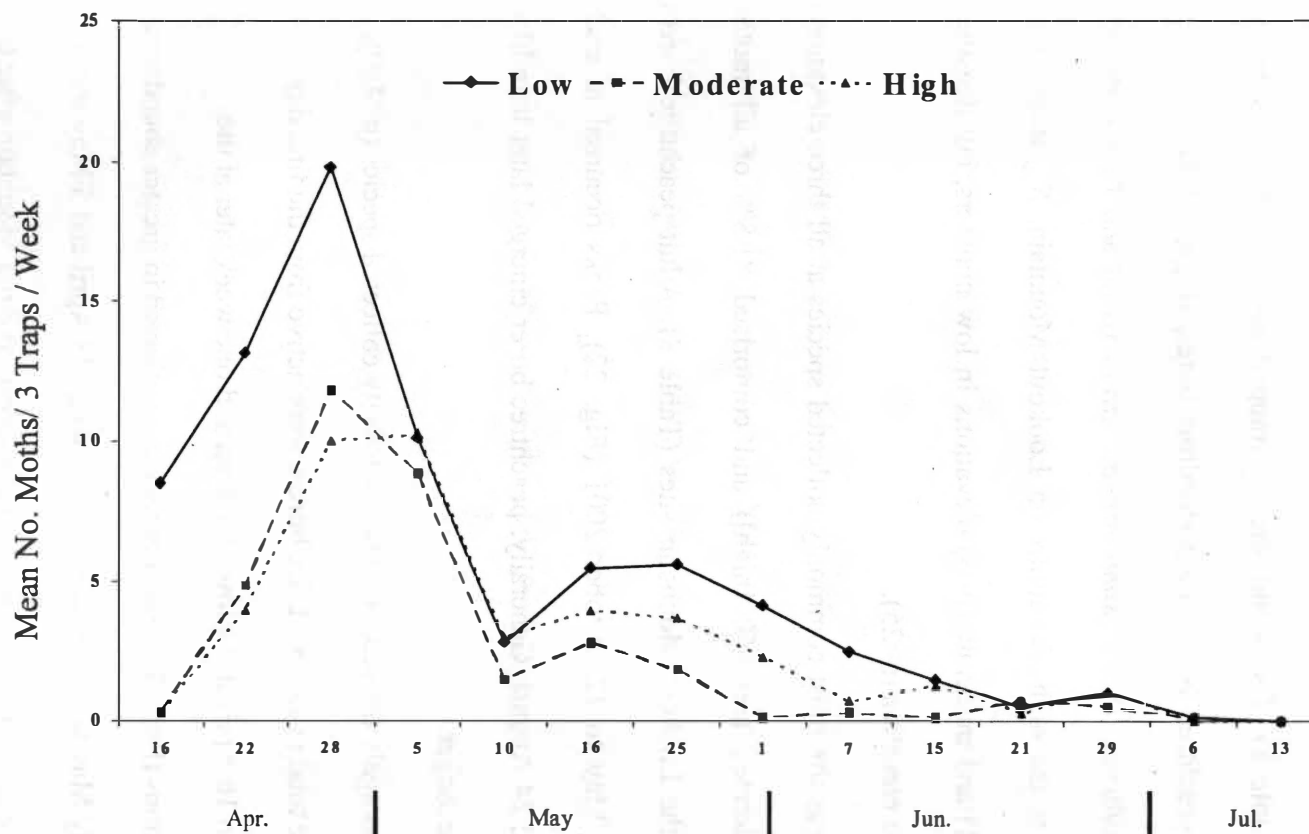


Fig. 21. Influence of elevation on seasonality of lilac borer, *Podosesia syringae*, at selected sites in southeastern Tennessee, 2001 (*P. syringae* were not collected after 6 July 2001).

Comparisons Among Three Elevations at Lookout Mountain

During 2001, 3,293 adult male sesiid moths, representing four genera and eight species, were collected in pheromone-baited traps among the three elevations on Lookout Mountain, Tennessee (Table 8). The sesiid species trapped included the: lilac borer, banded ash clearwing, peachtree borer, rhododendron borer, dogwood borer, lesser viburnum borer, *C. bassiformis*, and *P. simulans*. *S. scitula* (n=1) and *C. bassiformis* (n=3) were only found at the high elevations on Lookout Mountain. *S. fatifera* was collected at the low (n=1) and moderate (n=3) elevations in low numbers, but densities were greater at the highest elevation (n=25).

Peachtree borer was the most commonly collected species at all three elevations (1,122 [low], 912 [moderate], and 660 [high]) and comprised 81.8% of all moths (n=3, 293) collected at the Lookout Mountain sites (Table 8). Adult peachtree borers were collected from 16 May to 12 October 2001 (Fig. 22). Peaks occurred at each elevation between 12 and 24 August. Generally, peachtree borer emerged later than lilac borer and remained active longer.

The lilac borer was again the second most commonly collected species (n=480), representing 14.6% of the total (Table 8). Lilac borers were active from the first day samples were collected on 16 April at the low elevation and one week later at the moderate and high elevations (Fig. 23). Lilac borers were collected in greater abundance during late April and early May with peak densities between 28 April and 5 May for all elevations. No moths were collected from any of the sites on Lookout Mountain after 6 July. The remaining six clearwing species were collected in low numbers and collectively

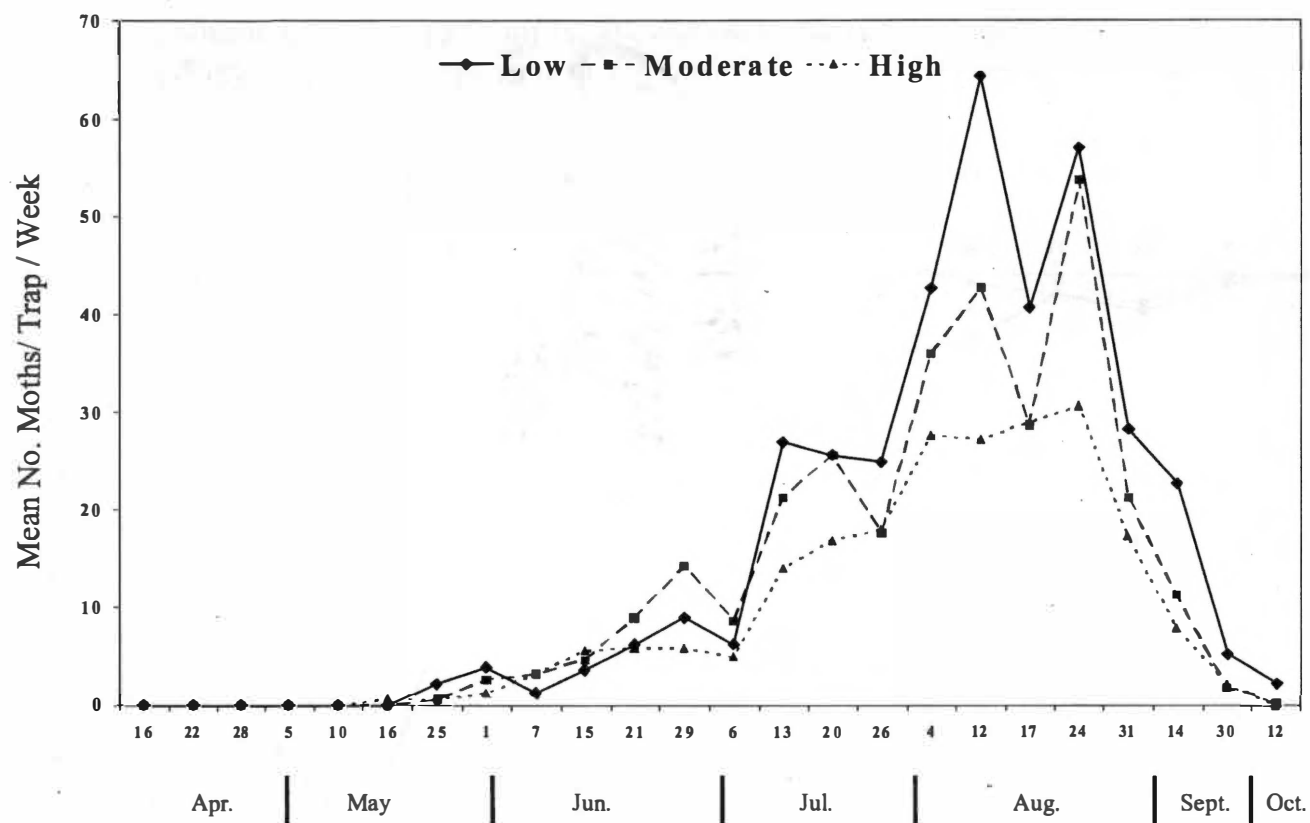


Fig. 22. Influence of elevation on seasonality of peachtree borer, *Synanthedon exitiosa*, at Lookout Mountain, TN, 2001.

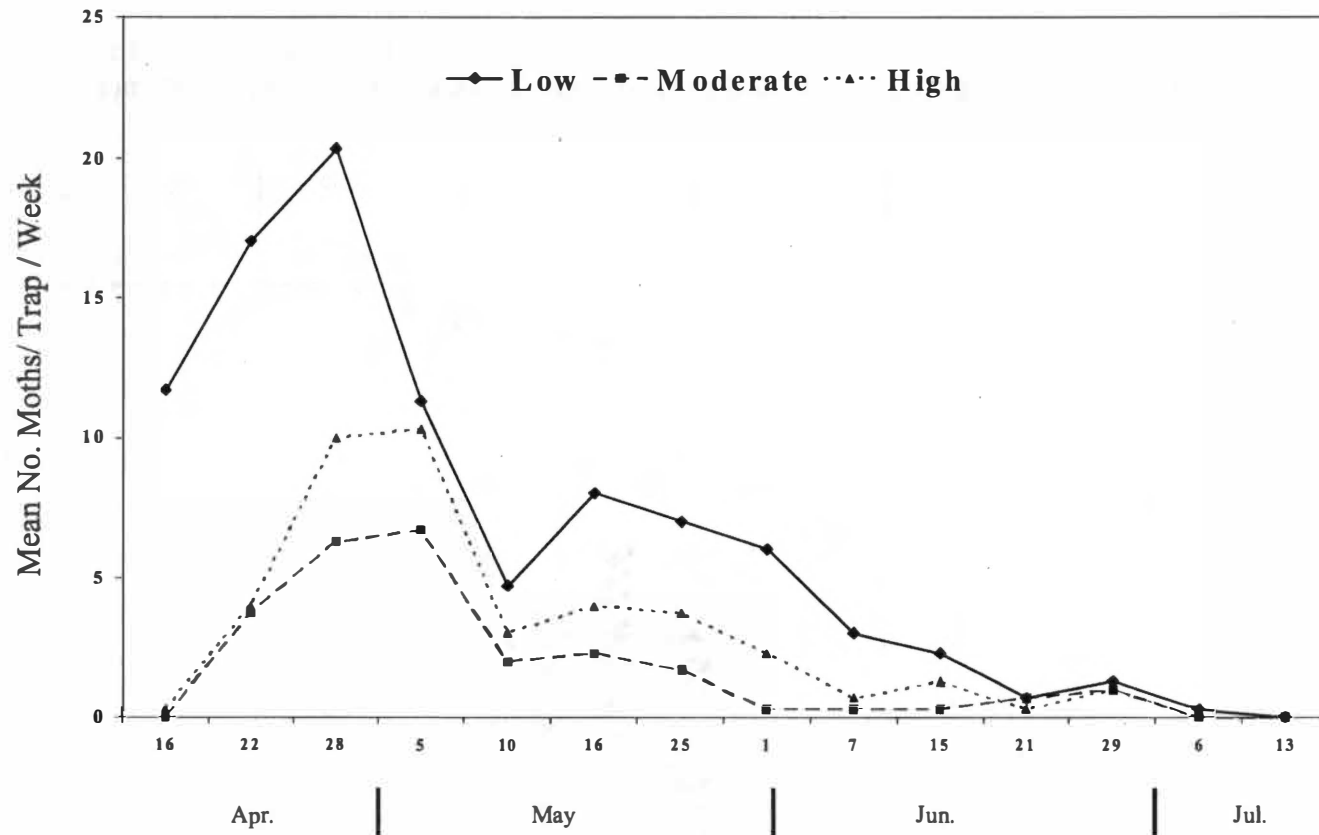


Fig. 23. Influence of elevation on seasonality of lilac borer, *Podosesia syringae*, at Lookout Mountain, TN, 2001 (*P. syringae* were not collected after 6 July 2001).

comprised only 3.6% (n=119) of all specimens (Table 8). Only one specimen of *S. scitula* was collected in 2001. As in 2000, number of moths collected in each trap may have been influenced by attractiveness of the pheromone and site factors such as temperature or wetness (i.e., dew, fog, and rain).

BOTH YEARS

Comparisons Among Combined Elevations

During this two-year study, 16,423 adult male sesiid moths, representing four genera and 10 species, were collected in pheromone-baited traps among the three elevations in southeastern Tennessee (Table 6). The sesiid species trapped included the: lilac borer, banded ash clearwing, peachtree borer, rhododendron borer, dogwood borer, lesser viburnum borer, *C. bassiformis*, *S. kathyae*, *S. rubrofascia*, and *P. simulans*. Peachtree borer compiled the greatest number of specimens collected during both years although populations declined between 2000 (n=9,141) and 2001 (n=5,692). Conversely, lilac borer populations increased between 2000 (n=564) and 2001 (n=780). Two species, *S. kathyae* and *S. rubrofascia*, were collected only during 2000, while *C. bassiformis* was collected only during 2001.

The flight phenology of peachtree borer differed slightly between the two years, with adult clearwings active ca. four days earlier and peak emergence seven days later in 2000 than 2001 (Fig. 15, 20). Densities of lilac borer also differed between the two years as they peaked earlier, and adults remained active longer, in 2000 than 2001 (Fig. 17, 21).

Elevation significantly influenced densities of adult lilac borers ($r^2 = 0.67$; $F = 4.28$; $df = 2, 6$; $p=0.0699$) and peachtree borers ($r^2 = 0.80$; $F = 12.46$; $df = 2, 6$;

$p=0.0073$) when all data were combined for 2000 and 2001 (Table 7). For both species, densities were significantly greater (ca. 1.4x - 2.3x) at the low elevation than at the moderate or high elevations. However, no significant differences ($p>0.05$) were detected between the moderate or high elevations.

Comparisons Among Three Elevations at Lookout Mountain

Over the two-year period, 8,084 adult male sesiid moths, representing four genera and 10 species, were collected in pheromone-baited traps among the three elevations on Lookout Mountain, Tennessee (Table 8). The sesiid species trapped included the: lilac borer, banded ash clearwing, peachtree borer, rhododendron borer, dogwood borer, lesser viburnum borer, *C. bassiformis*, *S. kathyae*, *S. rubrofascia*, and *P. simulans*.

Peachtree borer compiled the greatest number of specimens collected during both years although populations declined by almost one-half between 2000 ($n=4,398$) and 2001 ($n=2,694$). Conversely, lilac borer populations increased between 2000 ($n=326$) and 2001 ($n=480$). Two species, *S. kathyae* and *S. rubrofascia*, were collected only during 2001, while *C. bassiformis* and *P. simulans* were collected only during 2001.

The flight phenology of peachtree borer between the two years was similar, with peak emergence occurring between 12 and 24 August in both years (Fig. 18, 22).

Densities of adult lilac borer differed between the two years as densities peaked about two weeks earlier in 2001 than 2000 at the moderate and high elevations. (Fig. 19, 23).

Peak emergence at the low elevation occurred only one week later in 2001 than 2000.

iv. SUMMARY

In general, densities of peachtree borer and lilac borer were lowest at the high elevation, suggesting that the season-long cooler temperatures may influence populations of these two clearwing moth species. Cooler temperatures at high elevations may reduce plant stress, which is a key component in the susceptibility of many plants to clearwing larvae attack. In some urban and forest habitats, plant composition and size at higher elevations may be different when compared to lower elevations and may therefore affect clearwing densities. Temperatures may vary even among low elevation sites. For example, temperatures of landscapes within the metropolitan area of a large city are often several degrees warmer than temperatures in suburban or rural areas. Other factors such as host plant density and health, wetness (i.e., dew, fog, and rain) and attractiveness of the pheromone may also have influenced population densities of peachtree borer and lilac borer.

Because differences in population densities were detected at sites close together in a geographically similar area, predictive flight phenologies of clearwing moths should be adjusted to consider elevational differences within a region or area. Understanding the effect of temperature and other factors on clearwing moth densities and phenology would be important to a commercial nursery, landscape maintenance company, or homeowner, since pesticide applications used to control clearwings at higher elevations may need to be delayed as much as two weeks later than average forecast dates. A better understanding of the influence of elevation on emergence of clearwing moths would

improve the selection and timing of insecticide applications. Development, incorporation, and implementation of degree-day models for clearwing moth species at various elevations should be considered an important step in an effective integrated pest management program.

CHAPTER IV

CONCLUSIONS

Larvae of the clearwing moth family (Lepidoptera: Sesiidae) are pests of more than 100 species of woody and herbaceous plants. Injury to the living tissue of woody plants by clearwing larvae is a frequent problem in nurseries and home landscapes where damaged or stressed trees may be found (Engelhardt 1932, Potter and Timmons 1983c, 1983d, Solomon 1975). Species of *Podosesia* Möschler, *Paranthrene* Hübner, and *Synanthedon* Hübner are described by Solomon et al. (1981) as “notorious for economic damage” in ornamental and nursery plantings. Because much of their life cycle is spent beneath the bark of their host plant, clearwings are considered one of the most difficult pest groups to control (Nielsen 1978a, Warner and Hay 1985).

Since the availability of synthetic lures (i.e., pheromones), sesiid biology is now better understood (Duckworth and Eichlin 1977). Additionally, degree-day models, which consider the growth and development of insects as related to temperature, have also provided insights to insect phenology (Ascerno 1991). These new tools have improved the efficacy of insecticide applications against many borer species through accurate timing and reduction of unnecessary applications of insecticides (Nielsen 1978a).

Clearwing composition and localized temperatures may vary greatly from one geographical area to another and among varying elevations. Thus, monitoring local pest

species and establishing degree-day models for individual areas are essential to the development of strategies to successful time applications of insecticides (Ascerno 1991).

Because of the importance of the clearwing complex and the damage these larvae inflict on various species of woody and herbaceous plants grown for economic or aesthetic value, a two-year study was initiated in 2000 to determine species composition, assess influence of elevation on species composition, and assess seasonality of selected species of clearwing moths in southeastern Tennessee. Traps were placed in two geographically distinct areas of the state, including 1) five urban habitats in Hamilton County, in southeastern Tennessee and 2) two forest habitats in the Great Smoky Mountains National Park. Three pheromone bucket traps baited with a lure strip impregnated with 17.4 mg 97/3 z, z-3, 13 C19 acetate/e, e-3, 13 C18 acetate 91% purity were placed at each of the seven sites. Traps were monitored weekly from mid-April to early September and bimonthly from mid-September to mid-October.

During 2000 and 2001, 13 species (n=18,012) of adult male clearwing moths were collected. Peachtree borer, *Synanthedon exitiosa* (Say) (n=15,578), and lilac borer, also called ash borer, *Podosesia syringae* (Harris) (n=1,845), were the two most commonly collected species in both the forest and urban habitats during this two-year study. An oak borer, *Paranthrene simulans* (Grote) (n=347), was more abundant in 2001 than in 2000, supporting other studies that demonstrate that *P. simulans* has a two-year life cycle with primary emergence in odd-numbered years. The remaining 10 species (n=242) were collected in low numbers and represented only 1.35% of all clearwing moths collected.

Each species exhibited different emergence times, seasonalities, and peak densities during each season. The differences in adult emergence, activity, and seasonality may be influenced by many factors, including proximity of host plant to trap, number of traps, weather, or natural enemies (Braxton and Raupp 1995, Sharp et al. 1978).

In general, lilac borer was the first species to appear in both habitats and emerged from early April to mid-July. Peak emergence dates varied among habitats. In the urban settings, peak emergence for lilac borer was typically early to mid-May, while in the forest habitats emergence varied greatly between 2000 (mid-June) and 2001 (mid-May).

Peachtree borer generally did not emerge until late May, but remained active longer than lilac borer with the latest captures in mid-October. Peak emergence occurred during 2000 and 2001 in mid-August in the urban habitats and early to mid-July in forest habitats. Adult *P. simulans* were collected from early May to late July in 2001 with peak emergence occurring in mid-May and late June to mid-July in urban habitats and mid-June to mid-July in forest habitats.

Species composition and the influence of elevation on seasonality of the two most abundant species (lilac borer and peachtree borer) were assessed for 2000 and 2001 among the three elevations on Lookout Mountain and all five combined urban habitat elevations. Over the two-year period, 16,423 adult male sesiid moths, representing four genera and 10 species, were collected in pheromone-baited traps among the three elevations combined from the five sites in southeastern Tennessee. Peachtree borer (n=14,833) and lilac borer (n=1,344) compiled the greatest number of specimens

collected during both years. Elevation significantly influenced densities of adult lilac borers ($r^2 = 0.67$; $F = 4.28$; $df = 2, 6$; $p=0.0699$) and peachtree borers ($r^2 = 0.80$; $F = 12.46$; $df = 2, 6$; $p=0.0073$) when all data were combined for 2000 and 2001. For both species, densities were significantly greater (ca. 1.4x - 2.3x) at the low elevation than at the moderate or high elevations. However, no significant differences were detected between the moderate or high elevations. In general, densities of peachtree borer and lilac borer were lowest at the high elevation.

Data from this research suggest temperature changes among elevations may influence populations of peachtree borer and lilac borer adults. Because these differences in population densities were detected at sites close together in a geographically similar area, predictive flight phenologies of clearwing moths should be adjusted to consider elevational differences within a region or area. Additionally, continued monitoring of clearwing moths in urban and forest habitats can lead to a better understanding of emergence and species composition. This information may result in better timing of pesticide applications or other practices that support an integrated pest management approach to clearwing borer control.

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APPENDIX

PLANT COMPOSITION BY SITE AND TRAP

Appendix. Plant Composition by Site and Trap

Plant Species		Site 1 ^s			Site 2			Site 3			Site 4			Site 5		
		Trap			Trap			Trap			Trap			Trap		
Common Name	Scientific Name	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Woody Trees and Shrubs																
Ash, White	<i>Fraxinus americana</i>							1	1							
Azalea, Deciduous	<i>Rhododendron</i> spp.			1*	1	10		15				1				1
Azalea, Evergreen	<i>Rhododendron</i> spp.													35		27
Azalea, Flame	<i>Rhododendron calendulaceum</i>														18	
Basswood	<i>Tilia americana</i>						2									
Beech, American	<i>Fagus grandifolia</i>											1				
Black Cherry	<i>Prunus serotina</i>	2			2				2	3	2	2				
Black Cherry (saplings)	<i>Prunus serotina</i>						3	1							10	
Blueberry	<i>Vaccinium ashei</i>															1
Bradford Pear	<i>Pyrus calleryana</i> 'Bradford'									2						
Buckeye, Yellow	<i>Aesculus flava</i>								1							
Catalpa	<i>Catalpa</i> sp.						1									
Crapemyrtle	<i>Lagerstroemia</i> spp.							8								
Dogwood	<i>Cornus florida</i>	10		3	1	1	7	1		4	10		9	1		3
Dogwood (saplings)	<i>Cornus florida</i>			50												
Eastern Red Cedar	<i>Juniperus virginiana</i>			1		1									1	
Elm, Slippery	<i>Ulmus rubra</i>	1	1	1												
Euonymus	<i>Euonymus</i> sp.					m ^t										
Forsythia	<i>Forsythia</i> sp.							10								
Ginkgo	<i>Ginkgo biloba</i>							1								
Hackberry, Sugar	<i>Celtis occidentalis</i>		6					1								
Hemlock	<i>Tsuga canadensis</i>		3	1	1	1	7				10					
Hickory (undetermined)	<i>Carya</i> sp.					1						1	m			
Hickory, Mockernut	<i>Carya tomentosa</i>										2					
Hickory, Shagbark	<i>Carya ovata</i>													2		

[illegible]

Plant Species		Site 1			Site 2			Site 3			Site 4			Site 5		
		Trap			Trap			Trap			Trap			Trap		
Common Name	Scientific Name	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Rhododendron	<i>Rhododendron</i> spp.	11	3		10	13		4	17	3	21	22	25	19	18	
Sassafras	<i>Sassafras albidum</i>			1					2	1	3					
Silverbell	<i>Halesia corolina</i>		1													
Sourwood	<i>Oxydendrum arboreum</i>											1				
Spruce	<i>Picea</i> sp.					1										
Sumac	<i>Rhus</i> sp.															8
Sweetgum	<i>Liquidambar styraciflua</i>	m		1						3		1				
Sycamore	<i>Platanus occidentalis</i>								3							
Tulip Poplar	<i>Liriodendron tulipifera</i>			8					1		2					
Viburnum	<i>Viburnum</i> spp.			m				4								
Yucca	<i>Yucca</i> sp.				9	20	1	1								
Vines																
Grape	<i>Vitis</i> sp.			m					m							1
Ivy	<i>Hedera</i> sp.						m									
Japanese Honeysuckle	<i>Lonicera japonica</i>														m	
Muscadine	<i>Vitis rotundifolia</i>															1
Vinca	<i>Vinca</i> sp.					m		m								
Virginia Creeper	<i>Parthenocissus quinquefolia</i>					m	m		m							
Wisteria	<i>Wisteria</i> sp.						m									
Herbaceous Ornamentals																
Blackberry	<i>Rubus</i> spp.			m									m		m	m
Black-eyed Susan	<i>Rudbeckia hirta</i>			m												
Christmas Fern	<i>Polystichum acrostichoides</i>													3		
Columbine	<i>Aquilegia</i> sp.		m													
Daisies	<i>Chrysanthemum</i> sp.			m												
Daylilies	<i>Hemerocallis</i> spp.					m		m								
Fern	Undetermined			m	m	m	m		m							

Plant Species		Site 1			Site 2			Site 3			Site 4			Site 5		
		Trap			Trap			Trap			Trap			Trap		
Common Name	Scientific Name	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Hosta	<i>Hosta</i> spp.							m								
Iris	<i>Iris</i> spp.					m		m								
Liriope	<i>Liriope muscari</i>					m										
Money Plant	<i>Lunaria annua</i>						m								m	m
Poke	<i>Phytolacca americana</i>														1	10
Primrose	<i>Primula</i> sp.		m													
Spiderwort	<i>Tradescantia virginiana</i>						m									
Trillium	<i>Trillium</i> spp.						m									
Various Bulbs	Undetermined						m									
Virginia Bluebells	<i>Mertensia virginica</i>		m													

^s Site 1= Lookout Mountain, Reflection Riding Arboretum and Botanical Garden

Site 2= Lookout Mountain, Home Landscape

Site 3= Lookout Mountain, The Commons

Site 4= Elder Mountain, Home Landscape

Site 5= Hixson, Home Landscape

* m=multiple

^t numbers represent 930.25 sq.m. (30.5m x 30.5m)

VITA

Kelly Reed Jackson was born in Beaver Dam, Kentucky, on 13 April 1974. He is the son of Gary L. and Linda E. Jackson. He received his elementary and secondary education in Beaver Dam, Kentucky, graduating from Ohio County High School in May 1992. He attended Western Kentucky University in Bowling Green, Kentucky, where he received his Bachelor of Science Degree in Agriculture in May 1996. He married Ashley Ruth Maddox on 17 August 1997, and moved to Chattanooga, Tennessee, in September 1997 to begin work with the University of Tennessee as an Agriculture Extension Agent in Hamilton County, Tennessee. In the spring of 1999, he began study at The University of Tennessee, Knoxville, toward a Master's degree under the supervision of Dr. Jerome F. Grant. In August of 2002, Kelly received his Master of Science Degree with a major in Entomology and Plant Pathology.

Kelly R. Jackson continues to work as an Agriculture Extension Agent in Hamilton County, Tennessee. He is a member of the Tennessee Association of Agriculture Agents and Specialists, the National Association of County Agricultural Agents, Tennessee Entomological Society, The Entomological Society of America, and Gamma Sigma Delta Honor Society of Agriculture.

