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A Survey and Distributional Analysis of the park Coccoid Fauna of the Great Smoky Mountains National Park and Evirons

John Keith Watson
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To the Graduate Council:

I am submitting herewith a thesis written by John Keith Watson entitled "A Survey and Distributional Analysis of the park Coccoid Fauna of the Great Smoky Mountains National Park and Evirons." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant Sciences.

Paris L. Lambdin, Major Professor

We have read this thesis and recommend its acceptance:

M. L. Pan, J. F. Gant, C. D. Pless

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To the Graduate Council:

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A SURVEY AND DISTRIBUTIONAL ANALYSIS OF THE COCCOID FAUNA OF THE GREAT SMOKY MOUNTAINS NATIONAL PARK AND ENVIRONS

A Thesis

Presented for the

Master of Science Degree

The University of Tennessee, Knoxville

John Keith Watson

August 1988

This thesis is dedicated to my wife, Ms. Ruth A. Barber, and my children, Erik Christopher Watson, Shane Nicholas Watson, and Dawn Nicole Watson. Together, they have shown me the meaning of love and life.

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Words cannot express the tremendous feeling of reward I feel for the friendship and love of Ms. Ruth A. Barber which she gave so freely during the course of this study. I cherish her involvement, encouragement, and enduring support through the final episodes of this project. Thank you very much.

ABSTRACT

This comprehensive study on the coccoids (Homoptera: Coccoidea) of the Great Smoky Mountains National Park (GSMNP) resulted in the collection of fifty-three species representing six families from which seven new collection records for Tennessee were obtained. Six species were discovered that possibly represent new species. Analysis of distribution and host relationships are provided. Keys to the families, genera, and species are provided as well as descriptions of scale covers or tests and distinguishing morphological characters of the adult females.

A higher number of species were collected at lower elevational vegetative types and decreased inversely with elevation ($y = 17.104 - 8.6125e - 3x$; $R^2 = 0.679$) as did the number of infestations sampled ($y = 38.301 - 1.1970e - 2x$; $R^2 = 0.577$). One exception to this relationship was the occurrence of a slightly higher number of species recorded and number of infestations sampled on the grassy balds at higher elevations.

Coccoid distributions were positively correlated to host diversity. The hemlock-hardwood (HH) and the oak-chestnut (OC) cover types supported more species than any other forest cover type. Many species were polyphagous and cosmopolitan, and other species had restricted hosts and a limited distribution. More species were collected in

previously cutover and cultivated areas than any other type of vegetative habitat.

Fifty-six plants in 27 families and 40 genera were recorded as coccoid hosts in the GSMNP. More species of Pinaceae and Rosaceae were recorded as hosts for coccoids and trees in the family Betulaceae supported more species than any other host family.

Based on Shannon-Weaver diversity index values, thirty-three species were considered to be rare and only two species, Parthenolecanium corni (Bouche) (European fruit lecanium) and Abgrallaspis ithacae (Ferris) (hemlock scale), were considered to be abundant. P. corni was collected from 25 hosts from a wide elevational range and represented the greatest potential to damage hosts in the GSMNP.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

The Great Smoky Mountains National Park (GSMNP) is an international biosphere reserve that embodies a pristine wilderness resource available to scientific investigators, educators, and recreationists. Estimated by geologists to be 200-300 million years old and unscathed by glacial movements of the Pleistocene (King and Stupka 1950), these mountains abound with a diversity of endemic flora and fauna unparalleled in the eastern United States (Hoffman 1964, Whittaker 1956). The Park serves as sanctuary to thousands of species of plants and animals whose continual interactions influence the static and often dynamic ecological succession (Colinvaux 1973) of the GSMNP. The richness of species and habitat diversity provide a resource ecosystem that the National Park Service (NPS) emphasized "must be maintained in absolutely unimpaired form for the use of future generations as well as those of our own time" (Carpenter 1982).

The introduction of exotic flora and fauna to the GSMNP has conflicted with this policy and has challenged and complicated management strategies for NPS resource managers and scientists (Hermann and Bratton 1977). Exotic species threaten the native vegetative cover of the GSMNP (Baron et al. 1975) and interrupt the long-range stability of the reserve (Cowles 1899).

Chestnut blight in the eastern United States destroyed the American chestnut, Castanea dentata (Marshall) Borkhausen. Rooting behavior of the European wild hog ravaged the Turk's-cap Lily along the Appalachian Trail from Clingmans Dome to Silers Bald and eliminated the rare Gray's Lily from the GSMNP (Anonymous 1978).

Insect infestations have had significant impact on the floral composition of the GSMNP. The most evident vegetational disturbance was created by the balsam woolly adelgid, Adelges piceae (Ratzeburg). The southward migration and colonization of the balsam woolly adelgid on Fraser fir, Abies fraseri (Pursh) Poiret, led to important changes in species composition and structure of the high altitude vegetational communities in the spruce-fir zones, threatening the existence of the Fraser fir (Eagar 1978).

Periodic epidemics of the indigenous southern pine beetle, Dendroctonus frontalis Zimmermann, "speed the successional conversion" (Nicholas and White 1984) of pine-dominated stands to open mixed pine-hardwood stands (Kuykendall 1978). Tree mortality in forests attacked by the southern pine beetle and balsam woolly adelgid increased additional risks to habitat preservation during forest fires (Nicholas and White 1984, 1985).

Coccoids of both endemic and exotic origin are known to occur in the GSMNP (Snyder 1957) and surrounding areas (Brimley 1938, Lambdin and Watson 1980), and are quite

often serious forest insect pests in North America (Baker 1972, Coulson and Witter 1984) and worldwide (Miller and Kosztarab 1979). Parr (1939) recorded 50% mortality of pitch pine, Pinus rigida Miller, trees in Cape Cod, Massachussetts, and other areas in the Northeast due to infestations of the gall pine scale, Matsucoccus gallicolus Morrison. Localized infestations of the magnolia scale, Neolecanium cornuparvum (Thro), on Magnolia spp. in Virginia resulted in the death of branches and small trees (Williams and Kosztarab 1972). The oystershell scale, Lepidosaphes ulmi (L.), devasted entire stands of ash, Fraxinus spp., in Ohio (Craighead 1950). Many other species of Coccoidea attack and injure forest vegetation (Baker 1972), but accurate records are lacking. Kosztarab (1977) estimated that annual losses and extra production costs of major commodities due to coccoid infestations, including plant propagation and forestry industries, totaled $500 million annually.

Coccoid populations are often higher in disturbed areas, and the magnitude of ecological studies concerning coccoids deal with disturbed areas (Miller and Kosztarab 1979). Most economically important infestations of scale insects were reported from cultivated plantings, nurseries, greenhouses, and other "urbanized" areas (Dekle 1976, Kosztarab 1963, Tippins 1971, Williams and Kosztarab 1972). Factors responsible for coccoid population disparity

between forested and disturbed areas have not been well documented, but Tippins (1971) postulated that populations of endemic species in disturbed habitats increased because of air pollution and lower levels of natural enemies. Populations of exotic pest species flourish due to isolation from their natural enemies, and endemic parasitoid and predator levels have not adapted to the exotic species. Disturbed areas in the GSMNP are prevalent (Pyle 1985) and provide coccoids with an ecological haven for favorable development.

Coccoids have been recorded from virtually every woody host plant known to occur in the GSMNP, including many of the non-woody plants from other localities (Dekle 1976, Hamon and Williams 1984, Kosztarab 1963, Lambdin and Watson 1980, Williams and Kosztarab 1972). These insects pose an economic and biotic threat (Miller and Kosztarab 1979) to the perpetuation of the GSMNP.

Comprehensive studies concerning the impact of insects on vegetational communities in the GSMNP are limited and deal primarily with restricted plant communities (Eagar 1978, Grimm 1963) or specific taxa (Cole 1940, Wray et al. 1963). The coccoid taxa of the GSMNP have not been investigated and are poorly understood. Basic biosystematic research to determine those species of scale insects present in the GSMNP and their ecological importance is needed to provide park managers the necessary

information for implementation of management strategies toward target species.

II. LITERATURE REVIEW

The Great Smoky Mountains (GSM) are the largest and highest part of the Southern Appalachian Highlands, the Unaka Mountains, and are situated southwest to northeast between the cities of Knoxville, Tennessee, and Asheville, North Carolina (King et al. 1968). Although the GSM are geologically very old and have reached physiographic maturity (Fenneman 1938), weather resistant rock formations have persisted and rugged topography remains a common feature of the landscape. The main crest of the GSM rises above 1525 m (5000 ft) for 58 km and 16 peaks of the GSM are above 1830 m (6000 ft) in elevation. The unique assemblage of flora and fauna of the Southern Appalachian Mountains was recognized by Bartram (1791) and subsequent wilderness conservationists (Campbell 1960) and efforts were initiated to protect the GSM. In 1926, the United States Congress established the GSMNP (Campbell 1960).

Present day floral and faunal associations in the GSMNP resulted from geological events and, more recently, intervention of mankind. Geologically, most rocks of the GSM are metamorphic sedimentary rocks of the Ocoee series deposited in pre-Cambrian time, long before the mountains were formed (King et al. 1968). The mountain ranges were formed when crustal movements and upheavals of the earth's surface occurred in the late Paleozoic era, about 200

million years ago (Stose and Stose 1949). The Southern Appalachian Mountains were untouched by the glacial advances of the Pleistocene, but some evidence indicated a timberline existed on the higher peaks (King and Stupka 1950). Glaciation and climatic fluctuations during the Pleistocene epoch destroyed many of the western and northern floral associations, but conditions in the Southern Appalachians were generally less disturbed. The variety of moisture, elevation, and habitats provided conditions that harbored and provided sanctuary to much of the Tertiary flora and fauna (King and Stupka 1950).

Human intervention within the last 200 years caused widespread disturbance in the GSMNP through settlement activities and commercial exploitation (Pyle 1985). Extensive second growth areas in the lower valleys and slopes resulted (Whittaker 1956). Death of the American chestnut altered forest composition and allowed reproduction of other tree and shrub species (Woods and Shanks 1957). Similar disturbances opened the forest canopy to invasion of shade intolerant plant species and altered stand composition and variety of plant cover (McCraken 1978). Consequently, the age and diversity of habitats resulted in a richness of flora and fauna unique to the GSM (Whittaker 1952).

The flora of the GSMNP creates a nearly continuous mantle of vegetation and has been the subject of exhaustive

studies (Cain 1930, 1931, 1935, 1943, 1944, 1945, Gilbert 1954, Hoffmann 1964, Jennison 1938, Miller 1938, Russell 1953, Shanks 1954, Sharp 1942, Stupka 1964, Whittaker 1952, Woods and Shanks 1957, 1959). Over 1300 flowering plants, including 130 native tree species, occur in the GSMNP (King and Stupka 1950), and Cain (1937) estimated 3.1% of the flora was endemic to the Unakas and an additional 8.5% was endemic to the Southern Appalachians. Extreme variable moisture conditions in the vegetative habitats are found from the mesic valleys to dry ridges, and temperatures range from austral to subalpine (Whittaker 1956). These conditions favored the development of extremely diverse faunal associations.

Vertebrate fauna of the GSMNP have been studied and well documented (McCrone et al. 1982), but inventories and invertebrate fauna research, especially regarding the Insecta, are insufficient and need exploration (Hermann and Bratton 1977). Previous insect research in the GSMNP was mostly compilations of systematic checklists of selected taxa (Barr 1969, Cole 1953, Etnier and Schuster 1979, Nelson 1979, Snyder 1957, Steyskal 1947a, 1947b, Wray et al. 1963) provided with collection records. Several studies investigated broad taxa (Alexander 1940, 1941, Cole 1940, Grimm 1963, Hribar et al. 1986, Sheldon 1985, Stoneburner 1977, Whittaker 1952) and discussed their distributions, and a few dealt with specific insect taxa

(Carpenter and Giordano 1955, Eagar and Hay 1977, Etges 1984, Gerhardt 1986, Kuykendall 1978) in particular habitats. Collections of Coccoidea from the GSMNP were limited, and before 1980 only five published records existed (Snyder 1957). These were Pulvinaria acericola (Walsh and Riley), Toumeyella liriodendri (Gmelin), Lepidosaphes ulmi (L.), Quadraspidiotus perniciosus (Comstock), and one unidentified species of mealybug (Homoptera: Pseudococcidae). Brimley (1938) provided an extensive list of Coccoidea from the mountains of North Carolina, but records were incomplete and specific collection areas or sites were not provided.

Coccoids are small, often minute sap-sucking insects of the order Homoptera in the superfamily Coccoidea (Borror et al. 1981). They range in size from less than 1 mm to over 30 mm and appear to casual observers as plant galls; hence the name "coccoid", meaning gall-like. Males and females of this group are modified from typical Homoptera, very specialized, and extremely varied in form and behavior (Miller and Kosztarab 1979). Neotenic adult females exhibit both sexual and parthenogenetic reproduction. They are wingless, often legless, and sedentary as adults. Males developed differently from females and exhibited complete metamorphosis, developing through a pupal stage, and in the advanced coccoids, through the prepupal stage (Miller and Kosztarab 1979). Mouthparts in the males are

lacking after the second instar molt, and wings, when present, are developed only from the mesothorax. The metathoracic wings are reduced to stubs or hamulohalteres. Males are extremely fragile and live only a few hours to one day (Beardsley and Gonzalez 1975). Males and females produce and secrete different types of waxes which they utilize to construct ovisacs and build protective coatings over their bodies (Miller and Kosztarab 1979, Stoetzel 1976).

The paurometabolic development of coccoids is variable and complex, but can be generalized in the following manner (Beardsley and Gonzalez 1975). Adult females are viviparous (egg laying) or ovoviviparous (bearing live young). Eclosion and live birth produce mobile first instars called crawlers. Crawlers migrate in search of suitable food sources and when found, they settle and insert their feeding stylets. At this time, many species become permanently affixed to the host for the duration of their lives. Males and females develop through a series of molts until they become reproductively mature. Females are similar in all stadia, except for an increase in size through successive molts. Males feed and develop through two or three nymphal molts, then develop through quiescent prepupal and pupal stages. Some primitive species are capable of movement throughout their life cycle. Development of these males and females is similar, but they

are able to remove their stylets from the host and move to alternate feeding sites.

Systematic classifications of the Coccoidea have been traditionally based on morphological characters of adult females (Ferris 1937, 1938, 1941, 1942, 1950, 1953, 1955). Recently, adult males, immatures, parasitoid complexes, and morphological details of mouthparts have been useful in differentiating taxa (Beardsley and Gonzalez 1975, Boratynski and Davies 1971, Koteja and Liniowska 1976, Rosen and DeBach 1978). Systematic treatments of coccoid families exist for the Archeococcoidea (Morrison 1928) and Neococcoidea (Ferris 1937, 1938, 1941, 1942, 1950, 1953, 1955, Kosztarab 1979, Lambdin and Kosztarab 1977, McKenzie 1967, Russell 1941, Williams and Kosztarab 1972) on a regional basis and few worldwide comprehensive treatments of Coccoidea have been attempted.

Approximately 6000 described species of scale insects in 22 recognized families (Kosztarab 1979) are distributed throughout all zoogeographical regions of the world in most botanical habitats from the tropics to the tundra (Miller and Kosztarab 1979). They are well established in most regions and have adapted to many different modes of life. Many species are detrimental to greenhouse plantings, forest vegetation, ornamental plantings, and citrus crops (Craighead 1950, Dekle 1976, McKenzie 1967, Williams and Kosztarab 1972). Some species are beneficial as potential

biological control agents of noxious weeds, and other species are beneficial as producers of dyes, waxes, resins, shellacs, paint bases, foods, and jewelry (Brown 1975, Donkin 1977, Goeden et al. 1967, Lambdin and Kosztarab 1977, Morrison 1928).

Host-coccoid relationships are complex and extremely variable, but Flanders (1970) and McClure (1977, 1980) observed and identified environmental factors that induced host plant immunity and resistance to coccoids. Many cosmopolitan species of coccoids are polyphagous; whereas monophagous or oligophagous species have restricted distributions. Thus, coccoid distributions are correlated to host distribution.

Vegetational and elevational distributions of insects in the GSMNP were investigated by Whittaker (1952) for major insect groups, Stoneburner (1977) for aquatic insects, Byers (1967) for Mecoptera, Sheldon (1985) for Plecoptera, Cole (1940) for Formicidae, and Carpenter and Giordano (1955) for Drosophila. Whittaker (1952) found that numbers of foliage insects were positively correlated with elevation and resulted from shorter developmental seasons at higher elevations, with a reduction of species on the grassy balds. Most investigations showed species distributions were inversely related with elevation and were influenced by altitudinal floristic zonation.

Altitudinal biotic zonation and climatic variations

resulted in the formation of unique floral associations in the GSMNP that directly influence the distribution of phytophagous coccoids. Colinvaux (1973) stated that vegetative diversity was greatest in the tropics and decreased with latitudinal progression, a change that was observed with the altitudinal gradient of mountains. He postulated that lower elevational habitats provided more exploitable niches for occupation, often resulting in higher species diversity. Colinvaux (1973) proposed that high elevational communities were subjected to extreme seasonal variations, and harsh climatic influences restricted the development of certain fauna. Shanks (1954) provided climatic data for the GSMNP that supported Colinvaux's hypothesis. Parameters that established biotic zones were complex and included climatic factors that were strongly influenced by geological events, particularly mountain formation and glaciation (Ross 1965). Merriman (1894) stated that temperature was the most important factor that influenced habitat zonation and ultimately species distribution. The success of a coccoid species in specific sites was shown to be directly related to host suitability and available plant nitrogen (McClure 1980, White 1978), conditions which were determined by interactions of climatic and environmental factors. Vegetative zones in the GSMNP reflect geologic, climatic, and elevational influences (King et al. 1968, Miller 1938)

and associated faunas have developed (Whittaker 1952).

The objectives of this study were to collect and identify the coccoid fauna in the GSMNP and environs; to determine their distrubutional patterns; and to assess the ecological significance of species collected.

III. MATERIALS AND METHODS

Scale insects were collected primarily from the Tennessee side of the GSMNP from June 1976, through November 1978, and from May through October 1987. Occasionally, collections from the North Carolina side of the GSMNP were made along the Appalachian Trail and from Andrews Bald. Specimens were also obtained from collections made in peripheral areas from the GSMNP and by Park officials from Andrews Bald, Chinquapin Ridge, Mount Sterling, Noland Creek, and Oconaluftee.

The study area (Figure 1) was divided into 16 blocks measuring 16 km^2 (9.94 mi) arranged south to north proceeding eastward. Miller's (1938) vegetational types of the GSMNP were used as sampling subsites within each block. The number of collecting trips and samples taken per subsite was reduced within blocks VI, XI, XIII, XIV, and XV with limited vegetative diversity. The number of collecting trips per block within other blocks was determined by vegetative diversity, trail and road accesses. Rugged topographic features often restricted collecting in some blocks. More trips were made to those sampling blocks that had a higher vegetative diversity and accessibility (Table 1) than to those sampling blocks with lower vegetative diversity and limited accessibility. More time was allocated for collecting in those blocks with a

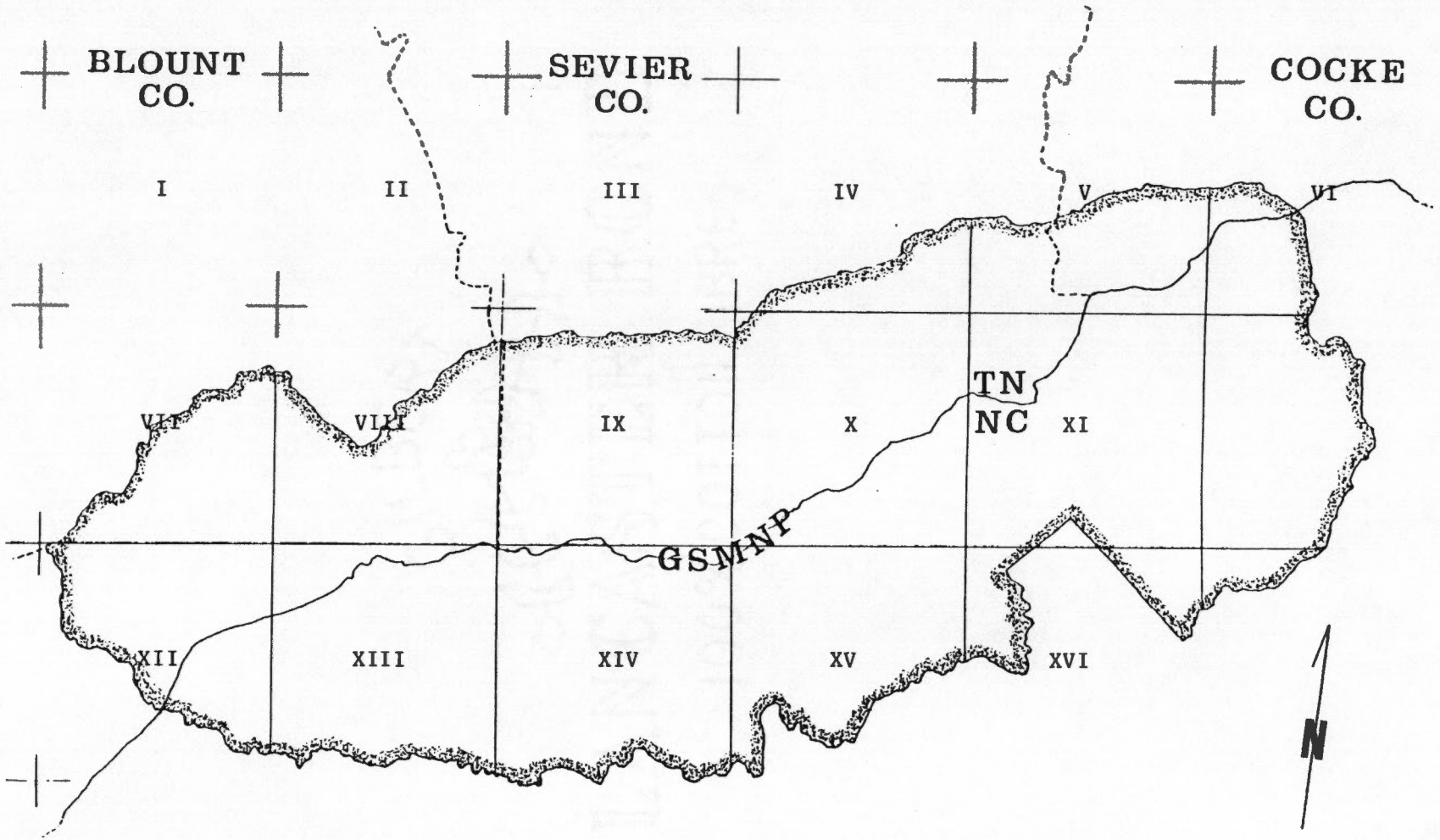

Figure 1. Sampling Area and Blocks in the Great Smoky Mountains National Park and Environs

Table 1. Number of Collecting Trips Per Sample Block in the Great Smoky Mountains National Park and Environs.

Sample Block	No. of Trips	Number of Samples
I.	3	1
II.	2	1
III.	1	0
IV.	8	34
V.	9	55
VI.	1	4
VII.	8	25
VIII.	16	51
IX.	25	67
X.	12	51
XI.	2	1
XII.	2	10
XIII.	2	1
XIV.	3	9
XV.	2	3
XVI.	1	0

higher vegetative diversity. Major trailhead locations were used as starting points for collecting trips. Names of collection areas are provided in Appendix B. Random collection sites were also selected along roadsides on the Tennessee side of the GSMNP and sampled. Sixty-eight collecting trips were made covering approximately 353 km (212 mi) of foot trails and 450 km (270 mi) of the accessible roadsides.

At each collection site, leaves, twigs, branches, and bark of trees and shrubs were examined for the presence of coccoids. Stems, leaf sheaths, and roots of herbaceous plants and grasses were also examined. Portions of the infested host plants were placed into 9.5 cm x 16.0 cm cellophane bags, labeled and taken to the laboratory for microscopic examination. When dead specimens were observed, additional cuttings of the host were collected in an effort to obtain live coccoid material. Inconspicuous species were often collected by this technique. Collected material was allowed to dry 24 hours to prevent mold growth before cellophane bags were sealed with paper clips (Kosztarab 1963) and stored in Cornell drawers in the University of Tennessee, Department of Entomology and Plant Pathology Insect Museum. Moss samples and leaf litter were placed in Berlese funnels and processed. Specimens were then placed in glass vials containing 70 percent ethyl alcohol.

At each collection site, elevation, major cover type, habitat condition (disturbed or non-disturbed), and any unique environmental factors were recorded for each infestation sampled. Elevations were estimated from a United States Geological Survey topographic quadrangle map of the GSMNP and vicinity with a ratio scale of 1:24000. For each species collected, the major cover type, host(s), location on host plant, stage of insect development, and presence of parasites and predators were recorded. Descriptions of the scale covers of the Diaspididae and external morphology of adult females of other families are provided when sufficient and suitable material was available. Measurements are presented in millimeters.

For species identification, specimens were cleared, stained, and mounted on microscope slides using Wilkey's Method (1962). Species identification and measurements were obtained utilizing a Wild Heerbrugg M-20 EB and Leitz Laborlux D phase contrast microscopes equipped with Floutar objectives at magnifications of 60-1000x.

Keys to the families, genera, and species that occurred in the GSMNP and environs were developed based on adult female morphology. Host plants were identified by specialists from the Departments of Forestry and Botany, University of Tennessee, and GSMNP officials. Collection data were compared with USDA and Tennessee Division of Plant Industries records to determine new host, county and

state records. Common names not approved by the Entomological Society of America were marked with an asterisk in the Treatment of Species section (Appendix A). The format used for Treatment of Species was modified from that designed by Miller (1974). Analyses of insect distribution and diversity were made using the Shannon-Weaver diversity index (Price 1984). Simple regression analysis was made for the number of species and the number of infestations sampled per 150 m elevational interval.

IV. RESULTS AND DISCUSSION

Fifty-three species of Coccoidea representing six families and 27 genera (Table 2) were collected from the GSMNP and environs. Distributions of scale insects in the GSMNP and environs are depicted in Appendix C. More species were collected and the number of infestations sampled were greater at the 300-500 m elevations than other elevational intervals. The number of species collected decreased inversely with elevation ($y = 17.104 - 8.6125e - 3x$; $R^2 = 0.679$) (Figure 2) as did the number of infestations sampled per elevational interval ($y = 38.301 - 1.9170e - 2x$; $R^2 = 0.577$) (Figure 3). A similar trend was observed with montane Formicidae in the Rocky Mountains (Gregg 1963), the Southern Blue Ridge Mountains (Van Pelt 1963), and the GSMNP (Cole 1940), and for aquatic insect ecosystems (Stoneburner 1977) and Drosophila (Carpenter and Giordano 1955) in the GSMNP. An increase in the number of species collected was evident at the 1600-1750 m elevation range (Figure 2) where grassy balds occurred. Although the vegetational diversity was relatively lower in the grassy balds (Whittaker 1956), the open nature of the balds and the intrusion of various tree species provided habitat suitable for several coccoids. Van Pelt (1963) and Cole (1940) reported an increase in numbers of formicid species on the balds due to the open nature and insolation of the

Table 2. Scale Insect Taxa of the Great Smoky Mountains National Park and Environs.

Family	Genus	No. of Species
Margarodidae	Matsucoccus	1
	Xylococculus	1
Pseudococcidae	Peliococcus	1
	Phenacoccus	2
	Pseudococcus	2
	Rhizoecus	1
	nr. Trionymus	1
	unidentified	1
	unidentified	1
Asterolecaniidae	Asterolecanium	1
Cerococcidae	Cerococcus	1
Coccidae	Mesolecanium	1
	Neolecanium	1
	Parthenolecanium	4
	Pulvinaria	2
	Toumeyella	2
Diaspididae	Abgrallaspis	4
	Acutaspis	1
	Carulaspis	1
	Chionaspis	11
	Diaspidiotus	4
	Hemiberlesia	1
	Lepidosaphes	2
	Melanaspis	1
	Quadraspidiotus	3
	Unaspis	1
	Velataspis	1
Total 6	27	53

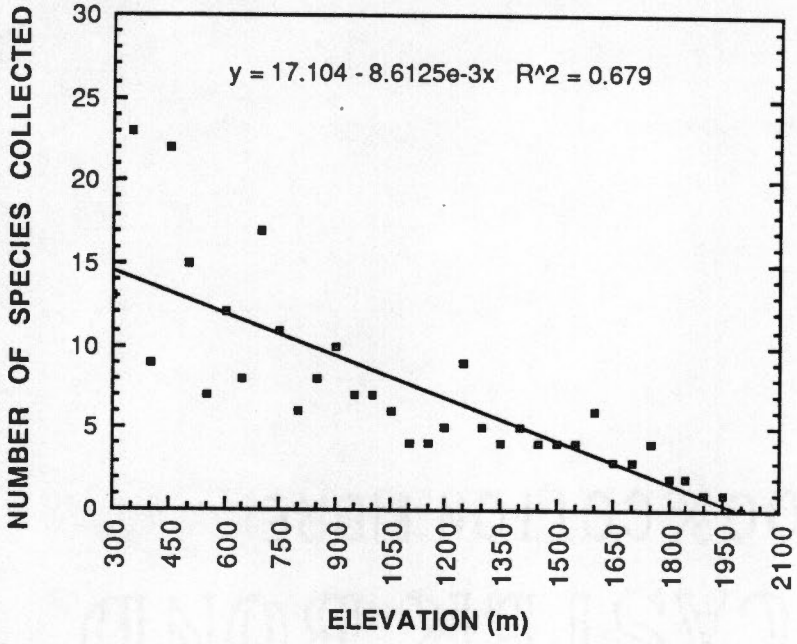

Figure 2. Elevational Distribution of Coccoid Species Collected in the Great Smoky Mountains National Park and Environs.

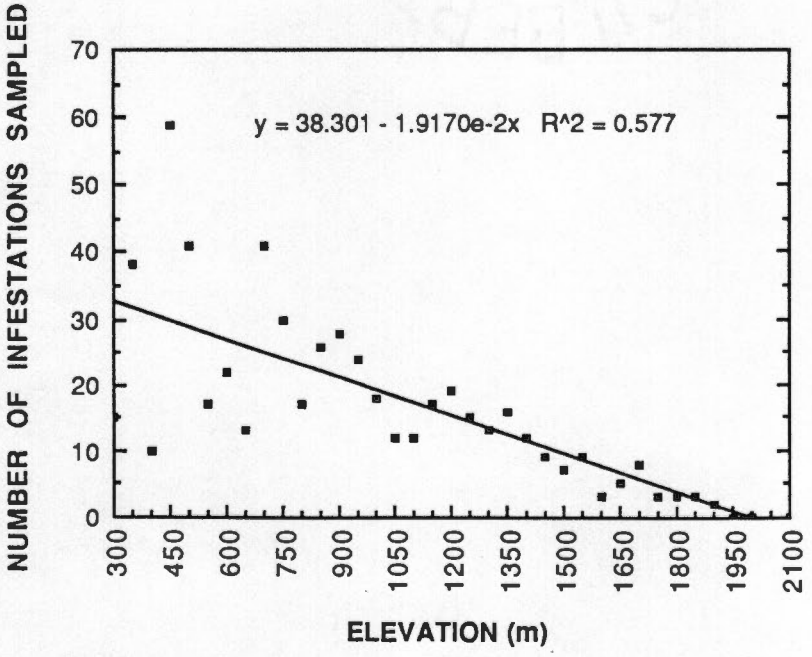

Figure 3. Elevational Distribution of the Number of Coccoid Infestations Sampled in the Great Smoky Mountains National Park and Environs.

the balds, but Whittaker (1952) reported a negative correlation with number of insect species.

The number of species collected from the families Diaspididae and Coccidae was higher in lower elevations and inversely related to elevation while species in the families Margarodidae, Pseudococcidae, Asterolecaniidae, and Cerococcidae did not follow this trend (Figures 4 and 5). The number of infestations sampled along the elevational gradient was also inversely related to elevation except for Margarodidae and Pseudococcidae (Figures 6 and 7). The abundance of the birch margarodid, Xylococculus betulae (Pergande), increased to 1400 m where optimal development of its hosts, Betula spp., occurred, and collections decreased above this elevation. Collections of Pseudococcidae were sparse and accurate distributional statements cannot be made, but collections were taken from a variety of vegetative zones at several elevations.

Collections of species in the genus Chionaspis (Diaspididae) reflected elevational distribution patterns previously mentioned (Figure 8). Six species were collected from the lower elevational (less than 1200 m) more diverse cover types and species numbers decreased inversely with elevation except for the presence of Chionaspis nr. platani Cooley at 1686 m. This species was collected from a stand of Viburnum cassinoides L.

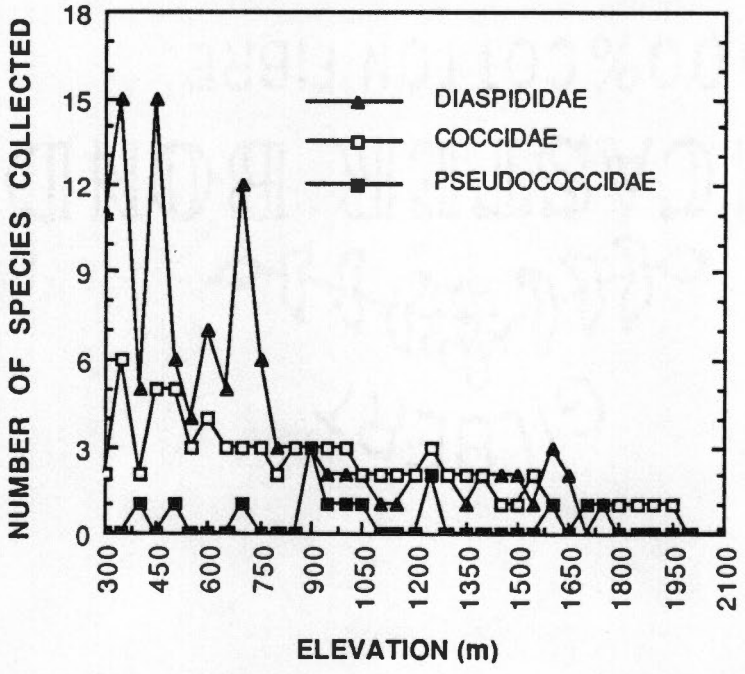

Figure 4. Elevational Distribution of Diaspididae, Coccidae, and Pseudococcidae Species Collected in the Great Smoky Mountains National Park and Environs.

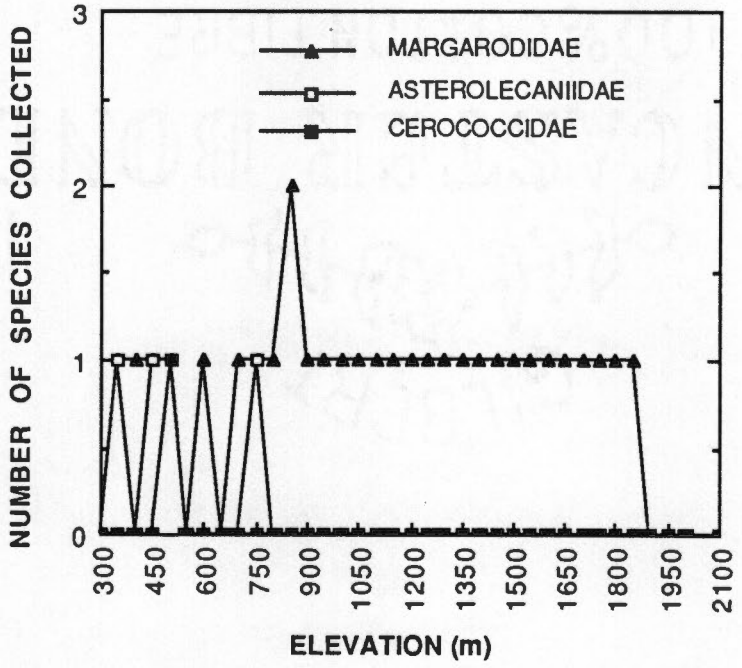

Figure 5. Elevational Distribution of Margarodidae, Asterolecaniidae, and Cerococcidae Species Collected in the Great Smoky Mountains National Park and Environs.

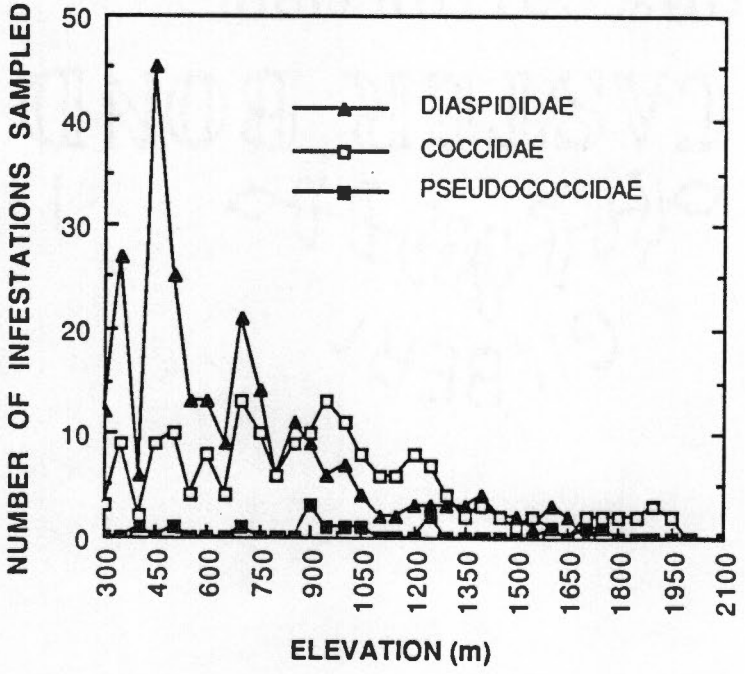

Figure 6. Elevational Distribution of the Number of Infestations Sampled of Diaspididae, Coccidae, and Pseudococcidae in the Great Smoky Mountains National Park and Environs.

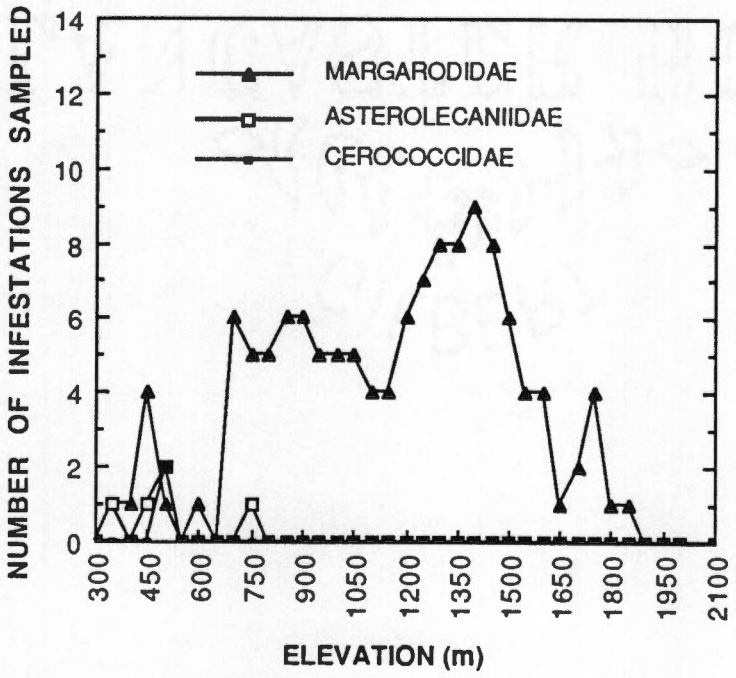

Figure 7. Elevational Distribution of the Number of Infestations Sampled of Margarodidae, Asterolecaniidae, and Cerococcidae in the Great Smoky Mountains National Park and Environs.

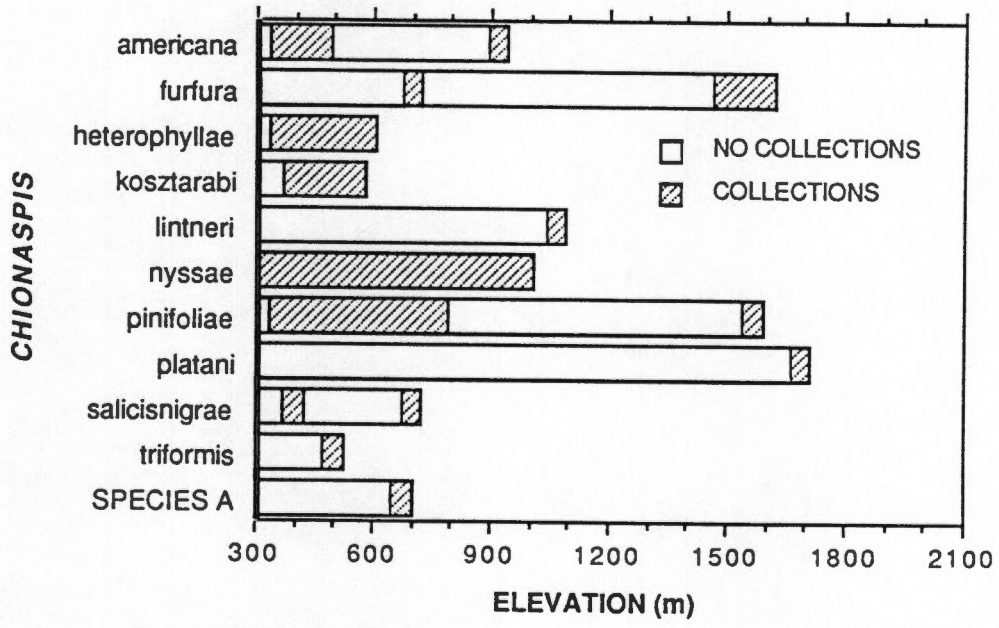

Figure 8. Elevational Distribution of Chionaspis spp. in the Great Smoky Mountains National Park and Environs.

(witherod) on an exposed disturbed trail edge on Thunderhead Mountain. The occurrence of two additional high elevation diaspidids, C. furfura (Fitch) and C. pinifoliae (Fitch), were restricted to narrow elevational ranges on Sorbus americana Marshall (mountain-ash) and Picea rubens Sargent (red spruce), respectively.

Fifty-six plant species in 40 genera representing 27 families, including leaf litter, were identified as hosts for scale insects and one root rhizoecus, Rhizoecus distinctus Hambleton, collected from the GSMNP (Appendix D). The dominant host plant families on which scale insects occurred were the Aceraceae, Betulaceae, Fagaceae, Pinaceae, and Rosaceae. Coccoids in the families Coccidae and Diaspididae were the dominant species collected from these and other host families (Table 3). Hosts in Betulaceae supported 20.8% of the total number (n = 11) of coccoids collected, more than any other host family.

The vegetative zones sampled had indefinite boundaries and a continuum existed from one type to another, except for heath balds which had more definite boundaries. The basic cover types with which scale insects could be associated were in descending order of diversity (based on the number of tree species present as determined by Miller 1938):

1). HH-Hemlock Hardwood, or Cove Hardwood;

2). OC-Oak Chestnut;

Table 3. Number of Genera (G) and Species (S) of Coccoids Collected from Host Families in the Great Smoky Mountains National Park and Environs.

Host Family	Coccoid Family											
	MA		PS		AS		CE		CO		DI	
	G	S	G	S	G	S	G	S	G	S	G	S
Aceraceae	0	0	0	0	0	0	0	0	2	3	6	7
Anacardiaceae	0	0	0	0	0	0	0	0	1	1	0	0
Asteraceae	0	0	1	1	0	0	0	0	0	0	0	0
Betulaceae	1	1	2	2	0	0	1	1	2	2	3	5
Buxaceae	0	0	0	0	0	0	0	0	1	1	0	0
Caprifoliaceae	0	0	0	0	0	0	0	0	0	0	1	1
Celastraceae	0	0	0	0	0	0	0	0	0	0	1	1
Compositae	0	0	1	1	0	0	0	0	0	0	0	0
Cornaceae	0	0	0	0	0	0	1	1	1	1	3	5
Cupressaceae	0	0	0	0	0	0	0	0	1	1	1	1
Ericaceae	0	0	0	0	0	0	0	0	1	1	0	0
Fagaceae	0	0	1	1	1	1	0	0	2	2	3	3
Hamamelidaceae	0	0	0	0	0	0	0	0	1	1	3	3
Juglandaceae	0	0	0	0	0	0	0	0	1	1	0	0
Magnoliaceae	0	0	0	0	0	0	0	0	4	4	0	0
Moraceae	0	0	0	0	0	0	0	0	1	1	0	0
Nyssaceae	0	0	0	0	0	0	0	0	2	2	2	2
Pinaceae	1	1	2	3	0	0	0	0	1	1	3	4

Table 3 (continued).

Host Family	Coccoid Family											
	MA		PS		AS		CE		CO		DI	
	G	S	G	S	G	S	G	S	G	S	G	S
Platanaceae	0	0	0	0	0	0	0	0	1	1	1	1
Rosaceae	0	0	1	1	0	0	0	0	1	2	2	3
Salicaceae	0	0	0	0	0	0	0	0	1	1	0	0
Santalaceae	0	0	0	0	0	0	0	0	1	1	0	0
Stryacaceae	0	0	1	1	0	0	0	0	1	1	2	2
Tiliaceae	0	0	0	0	0	0	0	0	2	2	1	1
Ulmaceae	0	0	0	0	0	0	0	0	1	1	1	1
Vitaceae	0	0	0	0	0	0	0	0	0	0	1	1
Leaf Litter	0	0	1	1	0	0	0	0	0	0	0	0

Note: MA-Margarodidae, PS-Pseudococcidae, AS-Asterolecaniidae, CE-Cerococcidae, CO-Coccidae, DI-Diaspididae.

3). WP-White Pine Hardwood;

4). YP-Yellow Pine Hardwood;

5). BB-Beech Birch Maple;

6). SP-Spruce Fir;

7). BD-Grassy Balds;

8). LS-Heath Balds or Laurel Slicks;

9). CU-Cutover, or Cultivated Areas;

10). BR-Burned Areas;

11). HC-Heavily Cut Areas.

As a result of logging practices, land clearing, and cultivation, types 9-11 were heavily disturbed areas when vegetative mapping occurred and they have retained their disturbed nature.

The number of species collected and the number of infestations sampled per cover type were inversely related to cover type diversity (Figures 9 and 10). The exception to this trend was the number of species and number of infestations collected in the WP type. Limited accessibility of this type association prevented extensive collecting resulting in only two species collected.

Associations between species and host plant taxa existed for 27 species; whereas other coccoids were polyphagous and exhibited non-specific host requirements. Host associations with coccoid families are depicted in Table 4. The birch margarodid was collected primarily from the BB and HH associations and Matsucoccus gallicolus

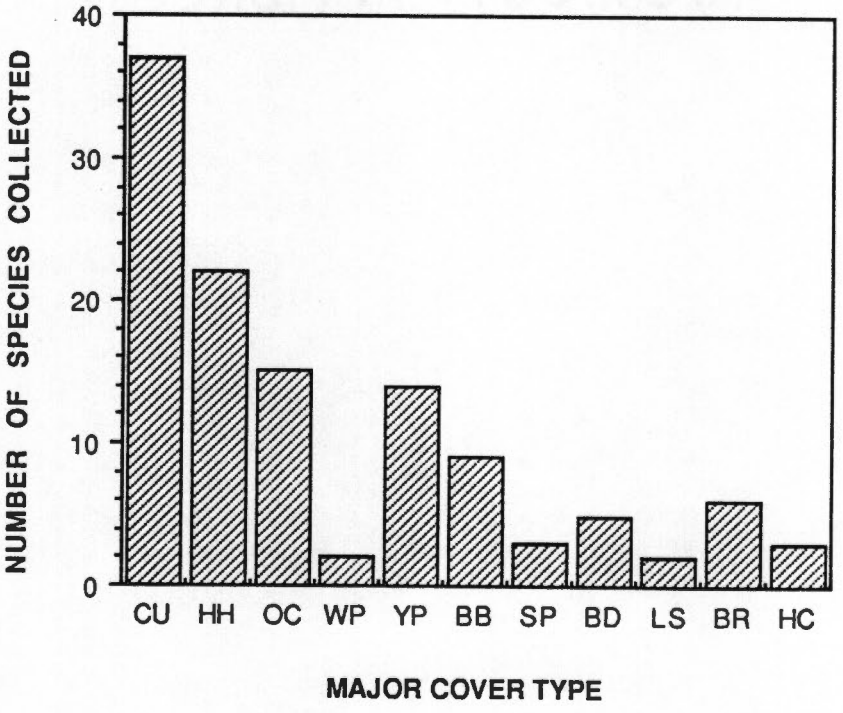

Figure 9. Number of Coccoid Species Collected in Major Cover Types in the Great Smoky Mountains National Park and Environs. Cu-Cutover or Cultivated Areas, HH-Hemlock Hardwood, OC-Oak Chestnut, WP-White Pine Hardwood, YP-Yellow Pine Hardwood, BB-Beech Birch Maple, SP-Spruce Fir, BD-Grassy Balds, LS-Heath Balds or Laurel Slicks, Br-Burned Areas, Hc-Heavily Cut Areas.

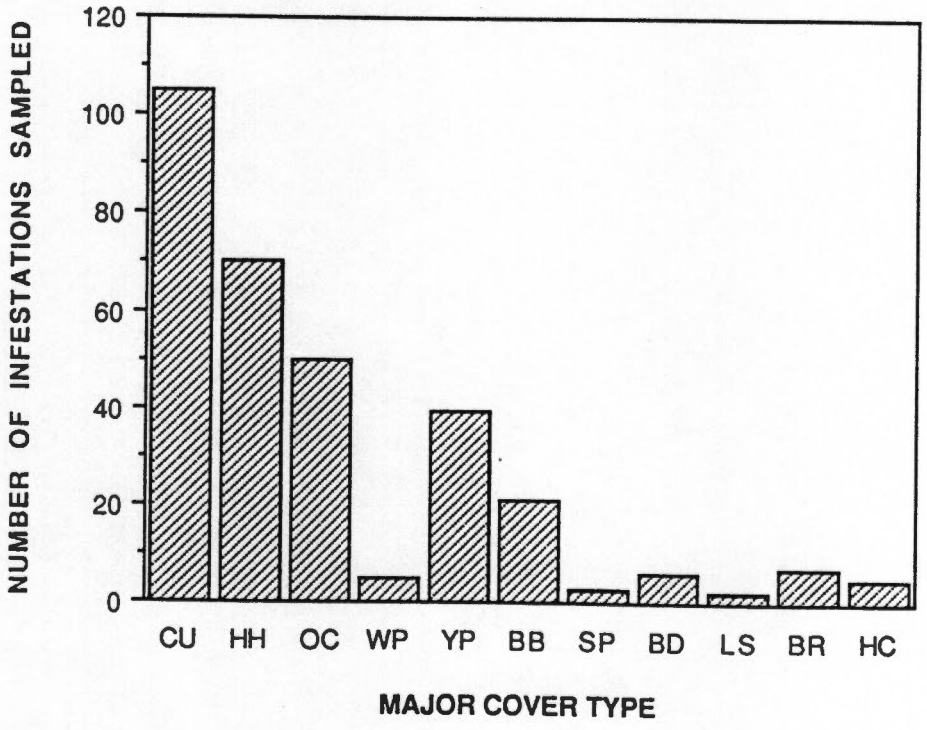

Figure 10. Number of Coccoid Infestations Sampled in Major Cover Types in the Great Smoky Mountains National Park and Environs. Cu-Cutover or Cultivated Areas, HH-Hemlock Hardwood, OC-Oak Chestnut, WP-White Pine Hardwood, YP-Yellow Pine Hardwood, BB-Beech Birch Maple, SP-Spruce Fir, BD-Grassy Balds, LS-Heath Balds or Laurel Slicks, Br-Burned Areas, Hc-Heavily Cut Areas.

Table 4. Total Number of Coccoid Species in Major Cover Types in the Great Smoky Mountains National Park and Environs.

Major Cover Type	Coccoid Family					
	MA	PS	AS	CE	CO	DI
Cutover Areas	2	2	1	1	8	23
Hemlock Hardwood	2	4	0	0	3	12
Oak Chestnut	2	0	1	0	6	7
White Pine Hardwood	0	0	0	0	0	2
Yellow Pine Hardwood	1	0	0	0	3	10
Beech Birch Maple	1	2	0	0	2	4
Spruce Fir	1	0	0	0	1	1
Bald (Grassy)	1	1	0	0	1	2
Laurel Slick	0	1	0	0	0	1
Burned Areas	0	1	1	0	2	2
Heavily Cut Areas	0	0	0	0	1	3

Note: MA-Margarodidae, PS-Pseudococcidae, AS-Asterolecaniidae, CE-Cerococcidae, CO-Coccidae, DI-Diaspididae.

Morrison, the gall pine scale, was collected from cover types which contained a high percentage of Pinus spp., the OC and YP associations. Collections of Pseudococcidae were concentrated in the HH type primarily, but more collections were made in disturbed areas. The oak pit scale, Asterolecanium minus Lindinger, occurred only on oak and collections were made primarily from the OC cover type. The pecan pit scale, Cerococcus parrotti (Hunter), was collected from cutover areas only. The majority of Coccidae collections were made from the HH, OC, and cutover areas. Fewer infestations were sampled in other cover types with a slight increase observed in the burned area, particularly Mount Buckley, where an extremely heavy infestation of Parthenolecanium corni (Bouche), the European fruit lecanium, was discovered on three hosts. Distribution of the Diaspididae was directly related to cover type diversity, and more infestations were sampled in the cutover areas as with other coccoid families.

More species were collected in the cutover areas. Excluding disturbed areas, more species were collected and the number of infestations sampled were higher in the HH cover type. As cover type diversity decreased, the sample frequency decreased, except as noted earlier in the WP type.

The major cover types were ranked according to tree diversity as determined by Miller (1938) and then a

diversity index was calculated based on the number of scale species collected in each cover type. This index provided a measure of niche breadth for each cover type (Figure 11). Niche breadth for forest cover types was greatest for the HH cover type and was lowest in the LS slicks. When all areas were considered niche breadth was highest in the cutover areas. When combined with burned areas and heavily cut areas, niche breadth was greater in disturbed areas than for non-disturbed areas. No species of coccoid was collected from all vegetative zones (Figure 12) and 50.9% (n = 27) of all species were collected from the cutover areas. Only one species, P. corni, was collected from nine cover types.

Diversity values for species collected ranged from 0.017 (rare) to 0.266 (abundant). More species were classified rare than were classified in other index categories combined (Table 5). Only two species were considered to be abundant and three were considered to be very common. Based on species diversity, number of infestations, cover type and sample block distribution, a species ranking was developed (Appendix E). In all categories, P. corni was considered to be the most abundant coccoid in the GSMNP. P. corni was present over a wide elevational range in nine vegetative types, excluding the WP and LS types. The increased number of infestations sampled at the 1700-1900 m elevational interval was due to

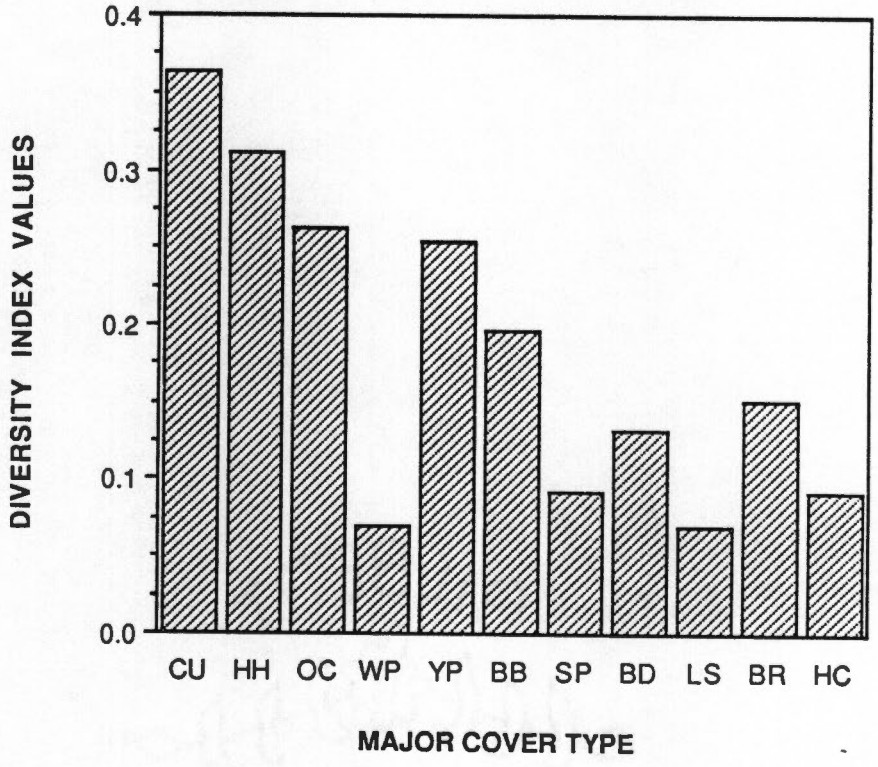

Figure 11. Shannon-Weaver Coccoid Diversity in Major Cover Types in the Great Smoky Mountains National Park and Environs. Cu-Cutover or Cultivated Areas, HH-Hemlock Hardwood, OC-Oak Chestnut, WP-White Pine Hardwood, YP-Yellow Pine Hardwood, BB-Beech Birch Maple, SP-Spruce Fir, BD-Grassy Balds, LS-Heath Balds or Laurel Slicks, Br-Burned Areas, Hc-Heavily Cut Areas.

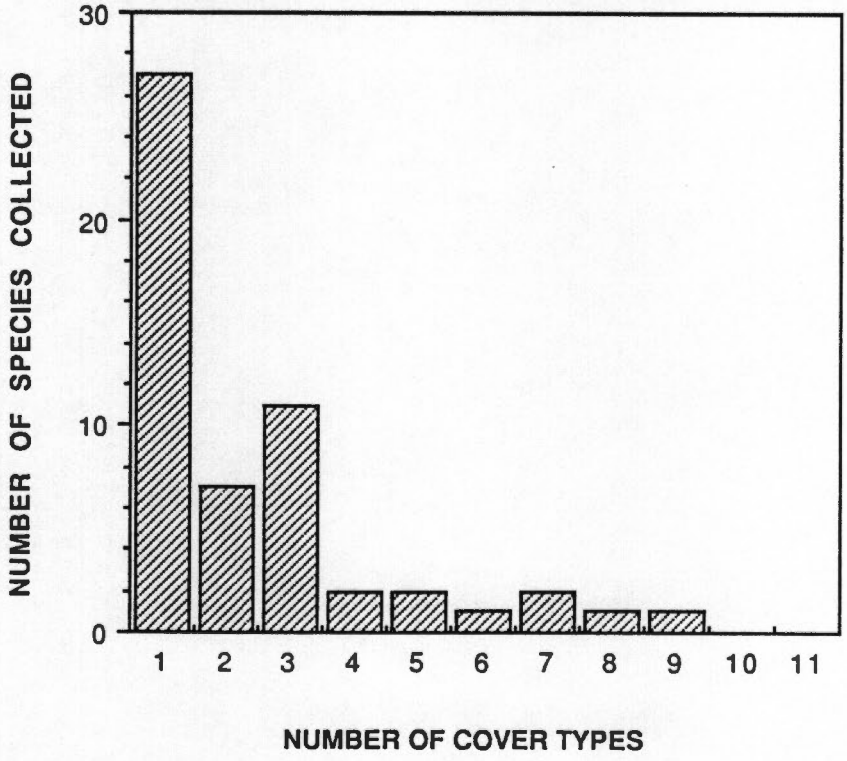

Figure 12. Number of Coccoid Species Collected from Number of Cover Types in the Great Smoky Mountains National Park and Environs.

Table 5. Shannon-Weaver Diversity Index, Species Rating, and Number of Species Collected Per Rating for Scale Insects Collected in the Great Smoky Mountains National Park and Environs

Shannon-Weaver Index	Rating	No. Species
> 0.216	Abundant	2
0.166-0.216	Very Common	3
0.096-0.165	Common	7
0.043-0.095	Uncommon	8
< 0.043	Rare	33

the infestation previously noted on the burned area on Mount Buckley.

The hemlock scale, Abgrallaspis ithacae (Ferris), was found only on eastern hemlock, Tsuga canadensis (L.) Carriere, at elevations from 300-1250 m, the elevational zone where eastern hemlock obtained optimal development. A. ithacae occurred more often in cutover areas and HH cover types and was one of two species recorded from the WP type.

Chionaspis pinifoliae (Fitch), the pine needle scale, was most prevalent at the lower elevations, 300-750 m, in the YP and cutover types. The pine needle scale and the hemlock scale were the only two species collected from the WP type.

The black gum scale, Chionaspis nyssae Comstock, was collected from black gum, Nyssa sylvatica Marshall, from cover types where black gum was a major component (i.e., the HH, OC, and YP cover types) at elevations below 1100 m.

The birch margarodid, Xylococculus betulae, was collected only from Betula spp. at the higher elevations where the BB cover type occurred.

The magnolia scale, Neolecanium cornuparvum (Thro), was collected from the hemlock-hardwood and oak-chestnut types at a wide range of elevations where Magnolia hosts occurred.

Coccoids were recorded from fourteen sampling blocks

in the GSMNP at elevations up to 1951 m. Collections from sample blocks IX and X were high due to the accessibility and disturbed nature of the vegetation of these areas.

V. CONCLUSIONS

The GSMNP was not covered by the glacial sheets of the Pleistocene epoch, and, as a result, coccoid species in the GSMNP consist of endemic and migrant species that are relicts of the Mesozoic or early Tertiary period (King and Stupka 1950). Some species migrated northward from the more tropical regions into the valleys of the GSMNP and others migrated southward from the more temperate regions of the north to the higher mountain summits in the GSMNP. Thus, the GSMNP represents a disjunct geographical region with a tremendous vegetative and environmental diversity that enhances the process of speciation and serves as a subcenter for species dispersal (Adams 1902). Many of the coccoids collected in the GSMNP showed extreme morphological variations and were collected from hosts not previously reported. Many adult females collected varied morphologically from the form of the type species. Three species of Pseudococcidae, including specimens from a possible new genus, could not be placed taxonomically. Two Pseudococcus spp. were determined as P. nr. acericola and P. nr. flaveolus because specimens did not conform to the traditional species concept.

Specimens of an unidentified Chionaspis sp. were collected, and one species was determined as C. nr. platani. Chionaspis nr. kosztarabi and C. triformis were

implicated in a morphologically variable species complex. These species represented either a morphological variant of a Chionaspis sp., a dimorphic species, or new species. The two latter species were both collected on Carpinus caroliniana Walter from similar elevations and, in one instance, the same tree. Morphological similarities between Diaspidiotus ancylus (Putnam) and D. osborni (Newell and Cockerell) also existed. Specimens of each species from different hosts resembled each other and often exhibited intermediate forms that were difficult to establish as separate species.

These species are genetic variations or new discoveries. Although dimorphic and trimorphic species of coccoids are known to exist, the occurrence of this many "forms" in the GSMNP indicated the presence of possibly undescribed coccoid species. Further biosystematic research to determine accurate taxonomic placement and ecological status of these species is needed.

Previous Coccoidea collections in the GSMNP were limited and this study presented the first extensive collections made for this group of insects in the Park. Seven species were recorded for the first time in Tennessee and the GSMNP, and 31 county records were established.

Altitudinal variation of climatic, vegetational, and other environmental conditions resulted in an altitudinal zonation of coccoid fauna that closely paralleled faunas of

similar latitudes with similar vegetative components (Britton 1923, Cooley 1899, Felt 1905, Kosztarab 1963). Lower elevational vegetative zones exhibited a diverse fauna that was similar to semi-tropical Nearctic regions (Beshear et al. 1973, Dekle 1976, Hamon and Williams 1984, Howard and Oliver 1985) and the higher elevations had a fauna similar to the more temperate harsh northern latitudes (Britton 1923, Cooley 1899, Dietz and Morrison 1916, Lugger 1900, McComb 1963). Host records from similar faunistic studies in other regions of the United States and the diverse flora of the GSMNP indicate that the coccoids presently recorded from the GSMNP comprise a small percentage of the coccoid fauna that probably exist, including the discovery of additional new species. As many as 250 species from 11 families could be expected to occur in the GSMNP.

Many of the species collected from the GSMNP have obtained population levels that may damage their host(s), but only P. corni damaged native vegetation on Mt. Buckley. This species perhaps represented the greatest potential of any coccoid of the GSMNP to cause widespread aesthetic and environmental damage. However, population levels of several species were high and potentially threatened their respective hosts and their biotic associations. Population levels of these species should be monitored on an annual basis to detect and accurately assess damage.

The success of coccoids depends on a multitude of environmental factors, but were not investigated in this study. The distribution of coccoids in the GSMNP was shown to be correlated to host availability and host distribution along an elevational gradient. Certain taxa of coccoids were recorded from one vegetational type only and were very specific in their host requirements. Others were polyphagous and were distributed over a wide host range at many elevations. Of particular interest was the high percentage of coccoids that were collected from disturbed areas. Thirteen species were recorded only from areas where the environment had been disturbed, and 62.6% (n = 33) of the species collected were recorded from a disturbed habitat. The majority of these samples were taken from areas that had been cultivated or logged by pioneers when the mountains were settled. These sites remain popular areas to visit and have retained their disturbed nature. The relatively higher number of samples taken from the balds also represents a significant trend for the Coccoidea.

Additional samples, particularly from the white pine-hardwood cover type, unique vegetative and geological areas, and remote sections of the GSMNP, are needed along with biosystematic and bioecological information to better understand the relationships GSMNP coccoids have with their environment. Evaluation of this information should enable

resource managers and scientists to identify areas where host-coccoid interactions could potentially develop into environmentally damaging infestations. Realistic management strategies toward threatening species of scale insects to preserve the GSMNP ecosystem could then be implemented.

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APPENDICES

APPENDIX A

TREATMENT OF SPECIES

TREATMENT OF SPECIES

Species are arranged phylogenetically beginning with the most primitive Margarodidae to the most advanced Diaspididae. Species are then arranged alphabetically by genus and species, except for the Diaspididae which are divided into two tribes, the Aspidiotini and the Diaspidini, and then arranged alphabetically by genus and species. Common names not approved by the Entomological Society of America are marked with an asterisk (*).

Key to the Families of Scale Insects in the GSMNP and Environs (Modified from Howell and Williams 1976)

1. Abdominal spiracles present.....Margarodidae
   Abdominal spiracles absent.....2

2. Anal opening covered with two triangular anal plates which form an operculum; abdomen with a well developed anal cleft.....Coccidae
   Anal opening covered with no more than one anal plate; anal cleft, if present, not well developed.....3

3. Eight-shaped pores present on dorsum.....4
   Eight-shaped pores absent on dorsum.....5

4. Ventral bilocular pores and sclerotized anal plates absent; antennae one segmented and without an associated cluster of five-seven locular pores.....Asterolecaniidae
   Ventral bilocular pores present and sclerotized anal plate present; antennae one segmented with an associated cluster of five-seven locular pores.....Cerococcidae

5. Abdomen terminating in a compound pygidium; anal opening simple; beak and antennae one segmented; legs usually absent or reduced; body covered by a secreted thin shield-like scale.....Diaspididae
   Abdomen not terminating in a compound pygidium; anal opening setiferous; beak and antennae with more than one segment; dorsal ostioles, ventral circuli, and trilocular pores usually present; body usually coated with waxy secretions.....Pseudococcidae

Family MARGARODIDAE Cockerell

Morrison's (1928) classification was used for current

taxonomic purposes. He recognized approximately 42 genera and 200 species. In the United States, 11 genera are represented by 41 species.

Matsucoccus gallicolus Morrison and Xylococculus betulae (Pergande) were collected from the GSMNP and environs. Specimens of M. gallicolus were separated from those of X. betulae by the absence of pores adjacent to the spiracular atria, thoracic spiracles were equal to or smaller than abdominal spiracles, no conspicuous anal tube was present, and were collected on Pinus spp. (Morrison 1928). Specimens of X. betulae had pores adjacent to the spiracular atria, thoracic spiracles larger than abdominal spiracles, conspicuous anal tube present, and were collected on Betula spp. (Morrison 1928).

Genus MATSUCOCCUS Cockerell

Matsucoccus is represented in North American by 13 species, all of which are recorded from Pinus spp. M. gallicolus was the only species recorded from the GSMNP.

Matsucoccus gallicolus Morrison, 1939

Common (or Suggested) Name: gall pine scale*.
Morphological Similarities: The gall pine scale was recognized by the abdominal spiracles, no pores near the spiracular atria, and 100-450 dorsal cicatrices (Parr 1939).
Field Description: The adult females were brown and produced a large ovisac under the bark scales of the host. Yellow colored crawlers were found in epidermal swellings on new growth in pit-like depressions (Parr 1939).
Habit: Dead adult females were collected under the bark scales.
Distribution: (Appendix C-1).
County: Blount; Sevier.
Locale: Anthony Ridge; Bote Mountain; Craig Cove; Metcalf Bottoms; Rabbit Creek; Sugarlands; Tremont.
Elevation: 396-610 m, 884 m.
Host(s): Pinus echinata Miller (shortleaf pine); P. rigida Miller (pitch pine); P. virginiana Miller (Virginia pine).
Biology: According to Parr (1939), in Massachussetts M. gallicolus was a univoltine species that overwintered in the egg stage beneath the bark scales. Eggs hatched approximately when new shoot growth began in the spring and the crawlers searched for suitable feeding sites on the new growth where they settled to feed. Development through maturity occurred at these sites within a

depression in the host tissue. In July the adult females migrated to the trunk or larger branches and deposited their eggs. Development on hosts in the GSMNP was probably similar. Only dead adult females were collected in the GSMNP.

Economic Importance: This species killed mature pitch pine in the Northeast and severely damaged trees 10-30 feet high (Parr 1939). No economic damage was observed in the GSMNP.

Remarks: This species was considered to be common in the GSMNP.

Genus XYLOCOCCULUS Morrison

Four species of Xylococculus are known to occur in North America, and only one species, X. betulae, occurred in the GSMNP.

Xylococculus betulae (Pergande), 1898

Common (or Suggested) Name: birch margarodid.

Morphological Similarities: X. betulae was distinguished from other Xylococculus spp. by the cluster of multilocular pores and cicatrices that surrounded the vulva (Morrison 1928).

Field Description: Adult females were bright orange, elliptical, and had well developed legs. Long, slender white anal tube filaments protruded from under the bark and indicated presence of this species.

Habit: Females of this species occurred beneath the bark flakes, in wounds, and in branch callouses.

Distribution: (Appendix C-2).

County: Blount; Cocke; Sevier; Swain, North Carolina.

Locale: Andrews Bald; Appalachian Trail, Low Gap-Cosby Knob-Mount Cammerer, Newfound Gap-Charlie's Bunion, Spence Field-Russell Field; Chimney Tops; Cosby Campground-Low Gap; Cosby Campground-Maddron Bald; Elkmont; Fighting Creek Gap-Laurel Falls; Fork Ridge; Gabes Mountain; Gregory Bald; Grotto Falls; Hannah Mountain; Jumpoff; Rainbow Falls-Mount LeConte; Sheep Pen Gap.

Elevation: 701-1860 m.

Host(s): Betula alleghaniensis Britton (yellow birch); B. lenta L. (sweet birch).

Biology: Overlapping generations allowed collections of all stages throughout the year in the GSMNP. Morrison (1928) stated mating occurred through a small hole near the anal opening. Adult females layed eggs within the previous instar exuviae. The mobile crawlers exited the exuviae and settled to feed in bark cracks and

crevices. The second-fourth instars were all legless cysts similar in shape, and these stages produced the anal filaments that transported honeydew. Related species in Japan required up to three years to complete one generation (Oguma 1919).

Economic Importance: Birch trees were killed by this species in the northern United States (Hubbard and Pergande 1898) but no economic damage was observed in the GSMNP.

Remarks: X. betulae was common in the GSMNP in areas where the hosts occurred. This species was distributed primarily in the northeastern United States and collections in the GSMNP represented the southernmost distribution of this species.

Family PSEUDOCOCCIDAE Ferris

This large and diverse family of scale insects contains approximately 900-1000 species in 180 genera. Approximately 275 species in 45 genera are widely distributed in the United States (Miller 1974).

Key to the Genera of Pseudococcidae in the GSMNP and Environs (Modified from McKenzie 1967)

1. Dorsal multilocular disk pores present and arranged in groups of three to six pores, each group with a tubular duct at its center.....Peliococcus
   Dorsal multilocular disk pores if present not so arranged, without a tubular duct in center.....2

2. Claws each with a conspicuous denticle; tarsal digitules setose; trilocular pores present; quinquelocular pores on venter only.....Phenacoccus
   Claws without a denticle; tarsal digitules capitate; trilocular pores present or absent; quinquelocular pores present on dorsal and ventral surfaces.....3

3. Anal lobes with paired conical cerarian setae; cerarii confined to anal lobes; .....nr. Trionymus
   Anal lobes with elongate cerarian setae or without cerarii; 4

4. With bi- or tritubular pores.....Rhizoecus
   Without bi- or tritubular pores.....Pseudococcus

Genus PELIOCOCCUS Borchsenius

This genus is represented by two Nearctic species and

13 Palearctic species (Ferris 1950). Only one species, P. serratus (Ferris) was collected near the GSMNP.

Peliococcus serratus (Ferris), 1925

Common (or Suggested) Name: serrate mealybug*.
Morphological Similarities: P. serratus was recognized by the cluster of both dorsal and ventral multilocular pores that surround the tubular ducts (McKenzie 1967).
Field Description: Only dead adult females were found and their bodies were dessicated and surrounded by ovisacs.
Habit: Adult females with ovisacs were found on the undersides of the leaves of the host.
Distribution: (Appendix C-3).
County: Sevier.
Locale: Glades.
Elevation: 457 m.
Host(s): Fagus grandifolia Ehrhart (American Beech).
Biology: Dead adult females with ovisacs were found in July on the underside of leaves. This conflicted with Russell's (1987) information that adult mealybugs migrated to the main trunk to lay eggs in knotholes and other protected places on the tree trunk. She also stated that immatures migrated up tree trunks to twigs, branches, and the underside of leaf surfaces. Two generations per year were reported by Russell in Maryland. Baker (1972) listed Betula spp. as a host for this species in the Northeast.
Economic Importance: No economic damage was observed.
Remarks: Ferris (1950) believed this species was morphologically distinct from other Peliococcus spp. and suggested a new genus be erected.

Genus PHENACOCCUS Cockerell

Of 34 species known to occur in the United States (Miller 1974), two species, P. nr. acericola King and P. nr. flaveolus, (Cockerell) were collected in the GSMNP. P. nr. flaveolus was distinguished from P. nr. acericola by the presence of dorsal median cerarii on the abdominal segments.

Phenacoccus nr. acericola King, 1902

Common (or Suggested) Name: maple phenacoccus*.
Morphological Similarities: The maple phenacoccus was distinguished by the presence of denticles in the tarsal claws, one circulus, and multilocular pores scattered over the entire dorsum (McKenzie 1967).
Field Description: One adult female collected was 3.0 mm long, bluish, and covered with a light waxy secretion.

Habit: One adult female was collected on new growth at the base of a host needle.
Distribution: (Appendix C-4).
County: Swain, North Carolina.
Locale: Fork Ridge Trail.
Elevation: 1768 m.
Host(s): Abies fraseri (Pursh) Poiret (Fraser fir).
Biology: One adult female was collected in June. Three generations per year were reported by Baker (1972) and nymphs overwintered.
Economic Importance: This species was of no economic importance in the GSMNP although it was a serious pest of sugar maple, Acer saccharum Marshall in the Northeast (Baker 1972).
Remarks: This species is recorded from Acer spp. primarily but (Ferris 1950) stated it occurred on Aesculus, Tilia, and Ostyra. Both host species, Aesculus octandra Marshall (yellow buckeye) and Tilia heterophylla Ventenat (white basswood), occurred where this collection was made and the presence of this species on A. fraseri could be accidental.

Phenacoccus nr. flaveolus (Cockerell), 1896

Common (or Suggested) Name: mountain mealybug*.
Morphological Similarities: This species could be distinguished by the presence of dorsal median cerarii on the abdominal segments.
Field Description: Immature females were 1.0-1.3 mm long, oval and covered with a light dusting of white wax.
Habit: Immature females were collected on the main stem near branch nodes.
Distribution: (Appendix C-5).
County: Sevier.
Locale: Charlie's Bunion.
Elevation: 1646 m.
Host(s): Betula lenta L. (sweet birch).
Biology: This species was recorded from nests of the ants, Lasius spp. (Ferris 1950). In the GSMNP, live immatures were collected on the bark in June and were not associated with ants.
Economic Importance: No economic damage was observed in the GSMNP.
Remarks: Ferris (1950) illustrated this species from specimens found on cranberry in Massachussetts, and associations with ant nests were not indicated. Collections of this species from aerial portions of the host perhaps indicated a complex of species or additional biological habits not previously reported.

Genus PSEUDOCOCCUS Westwood

This genus is represented by 20 North American species (Miller 1974) and contains many morphologically similar species. Only P. maritimus (Ehrhorn) was collected from the GSMNP.

Pseudococcus maritimus (Ehrhorn), 1900

Common (or Suggested) Name: grape mealybug*.
Morphological Similarities: P. maritimus was recognized by having tarsal claws with a denticle, few translucent pores on the hind tibiae, oral-collar tubular ducts of one size, and no discoidal pore near the eye.
Field Description: Females were covered with a gray waxy coating. Lateral filaments were present with the caudal pair the longest. McKenzie (1967) stated that ovisacs covered all but the head of the females.
Habit: Females were found on the bark, but Ferris (1950) stated that females occurred on all parts of the host.
Distribution: (Appendix C-6).
County: Cocke; Sevier; Swain, North Carolina.
Locale: Andrews Bald; Low Gap; Cherokee Orchard.
Elevation: 915 m, 1292 m, 1738 m.
Host(s): Betula alleghaniensis Britton (yellow birch); Halesia carolina L. (Carolina siverbell); Rubus sp. (blackberry).
Biology: Adult females were collected June through August in the GSMNP. Neiswander (1949) reported two generations per year in Ohio and Miller (1974) reported 2 to 2 1/2 generations per year in California. Miller also stated crawlers overwintered in the ovisacs produced by the females and migrated to the flower buds in spring. Development of subsequent generations occurred on the aerial portions of the host.
Economic Importance: This species was not economically important in the GSMNP, but McKenzie (1967) reported this species to be an economiocally important pest of grapes in California. Neiswander (1949) reported this species was a pest of Taxus spp. in Ohio nurseries.
Remarks: This species was considered to be rare in the GSMNP.

Pseudococcus sp.

Suggested (or Common Name): hemlock pseudococcus*.
Morphological Similarities: This species was probably P. maritimus but the poor condition of slide-mounted specimens made species identification impossible.
Field Description: Females were covered with a light dusting

of gray wax and lateral projections of waxy filaments.
Habit: Females were collected on the bark.
Distribution: (Appendix C-7).
County: Sevier.
Locale: Junglebrook.
Elevation: 701 m.
Host(s): Tsuga canadensis (L.) Carriere (eastern hemlock).
Biology: Fourth instar and adult females were collected in August from the GSMNP.
Economic Importance: This species was of no economic importance in the GSMNP.
Remarks: This species was considered rare in the GSMNP.

Genus RHIZOECUS Kunckel d'Herculais

This genus of primarily subterranean mealybugs is represented in North American by 26 species of which 24 species were recorded from the United States (Hambleton 1976). He also reported that only five species were collected outside of California and Florida. Rhizoecus distinctus (Hambleton) was the only species recorded from the GSMNP.

Rhizoecus distinctus (Hambleton), 1946

Common (or Suggested) Name: root rhizoecus*.
Morphological Similarities: R. distinctus could be recognized by having 46 to 74 tritubular cerores, non-protruding anal lobes each with three to four elongate setae, three smaller auxillary setae, and sparse multilocular disk pores on the head (Hambleton 1976).
Field Description: Females were oval and lightly covered with white wax. Specimens were preserved in 70% alcohol, resulting in external markings being altered.
Habit: This species was collected approximately 20 to 28 cm into the leaf litter and forest humus.
Distribution: (Appendix C-8).
County: Sevier.
Locale: Cherokee Orchard.
Elevation: 945 m.
Host(s): This species was found among detritus feeding on roots of unknown hosts.
Biology: Live adult females were collected in April.
Economic Importance: This species was not economically important in the GSMNP.
Remarks: This species represented a new state record for Tennessee.

Genus TRIONYMUS Berg

This genus of mealybugs is represented by 24 North American species (Miller 1974) collected mostly from Graminae. The species collected from the GSMNP could not be placed taxonomically because it is undescribed.

Genus nr. Trionymus

Common (or Suggested) Name: Rabbit Creek mealybug*.
Morphological Similarities: These specimens represent a new genus and species of Pseudococcidae. Nakahara (1977) stated this species resembled Trionymus by having trilocular pores on the body but specimens from Rabbit Creek had only a few of these pores near the spiracles. Specimens also resembled Heterococcus but Rabbit Creek mealybugs did not have quinquelocular pores. He identified the lot as near Trionymus, and Knutson (1987) recently confirmed that these mealybugs remain undescribed.
Field Description: Adult females were elongate, about 2.0-4.0 mm long, and covered with a light gray wax.
Habit: Adult females were found near ground level among the leaf sheaths.
Distribution: (Appendix C-9).
County: Blount.
Locale: Rabbit Creek.
Elevation: 427 m.
Host(s): Heterotheca graminifolia (Michaux) Shinners.
Biology: Live adult females were collected in September.
Economic Importance: This species was not economically important in the GSMNP.
Remarks: An evaluation of the genus Trionymus and allied groups is necessary before accurate taxonomic status of this species can be made.

Pseudococcidae # 1

Common (or Suggested) Name: aster mealybug*.
Morphological Similarities: This species was not positively identified and taxonomic placement was not available. Knutson (1987) indicated this species was possibly undescribed.
Field Description: Dessicated adult females within the ovisac were observed. Only the heads of the females were visible within the ovisac.
Habit: Adult females with ovisacs were collected from the leaf axils.
Distribution: (Appendix C-10).
County: Cocke.

Locale: Low Gap.
Elevation: 1293 m.
Host(s): Aster sp. (aster).
Biology: Adult females with ovisacs containing eggs were collected in July from the GSMNP.
Economic Importance: This species was not economically important in the GSMNP.
Remarks: Further evaluation of this species is needed pending proper identification by specialists. Adult females of P. maritimus were collected at the same site on Carolina silverbell, Halesia carolina L., The bodies of the females of these two species were enclosed within ovisacs and could be related.

Pseudococcidae # 2

Common (or Suggested) Name: hemlock bark mealybug*.
Morphological Similarities: This mealybug was not positively identified and taxonomic placement was not possible.
Field Description: Fourth instar females were 3.0 mm long, oval, and covered with a gray waxy coating. Lateral waxy filaments were present around the entire margin.
Habit: Females were found on the trunk.
Distribution: (Appendix C-11).
County: Sevier.
Locale: Grotto Falls.
Elevation: 915-1067 m.
Host(s): Tsuga canadensis (L.) Carriere (eastern hemlock).
Biology: Fourth instar females were collected in July in the GSMNP.
Economic Importance: This species was not economically important in the GSMNP.
Remarks: This species was considered to be rare in the GSMNP.

Family ASTEROLECANIIDAE Ferris

Ferris (1937) established the family that includes 250 worldwide and 31 North American species. Members of this family can be recognized by the presence of eight-shaped pores on the dorsum in a ventral submarginal band, one segmented antennae, ventral bilocular pores, and a sclerotized anal plate (Howell and Williams 1976).

Genus ASTEROLECANIUM Targioni-Tozzetti

Russell (1941) revised Asterolecanium and provided descriptions and illustrations for 156 species. Of 28

species Asterolecanium species represented in North America, only A. minus Lindinger occurred in the GSMNP.

Asterolecanium minus Lindinger, 1912

Common (or Suggested) Name: oak pit scale*.
Morphological Similarities: A. minus could be distinguished by the presence of fewer ventral four to five locular pores and fewer quinquelocular pores in the spiracular furrows (Russell 1941).
Field Description: Membranous, olive green adult female often with dorsal black mottling was enclosed under a slightly convex, waxy opaque yellow test 0.9-1.5 mm in diameter. White patches of wax were evident around the margin of the test, especially at the spiracular furrows. On some hosts, the test had a series of transverse ridges which radiated from a median carina. On other hosts, the test was smooth.
Habit: All stages were collected on twigs and branches, especially recent growth.
Distribution: (See Appendix C-12).
County: Blount; Sevier.
Locale: Foothills Parkway; Huskey Gap; Little Greenbriar; Rabbit Creek; Sugarlands.
Elevation: 366-549 m, 762 m.
Host(s): Quercus alba L. (white oak); Q. prinus L. (chestnut oak).
Biology: Parthenogenetic females laid eggs in mid-April. Crawlers migrated to new or one year old growth where they settled to feed. Second instars overwintered.
Economic Importance: Open galls or pits were produced by the feeding of this scale at the feeding site. The pits gradually enlarged as the female matured and eventually deteriorated and girdled the twig or stem. Pit degradation caused early leaffall, loss of vigor, and dieback and death of small twigs and branches (Koehler and Tamaki 1964). No economic damage was caused to hosts in the GSMNP.
Remarks: The oak pit scale was originally collected and described from Quercus spp. in Italy (Lindinger 1912) and has since been recorded from various oaks in the eastern United States and California (Koehler and Tamaki 1964).

Family CEROCOCCIDAE Balachowsky

Cerococcidae was established by Koteja and Liniowska (1976) based on unique morphology of the mouthparts and included Asterococcus Borchsenius, Cerococcus Comstock, and Solenophora Maskell (Lambdin and Kosztarab 1977). The

family was distributed worldwide and contained approximately 58 species of which eight were Nearctic. Members of this family could be recognized by one segmented antennae with a cluster of five to seven locular pores, and a triangular-shaped sclerotized anal plate (Lambdin and Kosztarab 1977).

Genus CEROCOCCUS Comstock

Fifty-two species of Cerococcus were recognized by Lambdin (1987a) of which eight were Nearctic. Lambdin and Kosztarab (1977) revised Cerococcus and provided a detailed morphological examination of the genus. C. parrotti (Hunter) was the only species recorded from the GSMNP.

Cerococcus parrotti (Hunter), 1899

Common (or Suggested) Name: pecan pit scale*.
Morphological Similarities: No other member of the Cerococcidae with a North American distribution resembled C. parrotti. The pecan pit scale could be recognized by two pairs of cribriform plates, multilocular pores one to two pores wide, and six five-locular pores at the base of the antennae (Lambdin and Kosztarab 1977).
Field Description: The female tests varied from 2.0-4.0 mm in length, were gray to red, convex, with three dorsal longitudinal rows of waxy tubercles. A row of waxy tubercles was evident marginally (Howell et al. 1971).
Habit: This species occurred on small twigs near the end of branches near twig and leaf scars.
Distribution: (Appendix C-13).
County: Sevier.
Locale: Greenbriar.
Elevation: 503-518 m.
Host(s): Carpinus caroliniana Walter (American hornbeam); Cornus florida L. (flowering dogwood).
Biology: Howell et al. (1971) reported this species was univoltine and eggs were deposited in the fall and overwintered. Eggs hatched in spring, second instars occurred in early summer and males emerged in late summer. Young females were collected in August in the GSMNP.
Economic Importance: C. parrotti was not economically important in the GSMNP.
Remarks: Howell et al. (1971) discussed the morphology, systematics, and biology of the pecan pit scale.

Family COCCIDAE Linnaeus

All scale insects were originally placed in this inclusive family. Later, this group was given superfamily status and scale insects that resembled Coccus hesperidum L., the brown soft scale, were made members of the Coccidae. About 1000 species in 100 genera are represented worldwide. The fauna of the Nearctic region contains approximately 85 species in 25 genera (Hamon and Williams 1984). Ten species in five genera were represented in the GSMNP.

Key to the Genera of Coccidae in the GSMNP and Environs (Modified from Hamon and Williams 1984)

1. Legs reduced, less than twice the length of thoracic spiracles.....2
   Legs well developed, at least twice the length of thoracic spiracles.....3

2. Dorsum with dense pattern of small eight-shaped pores; abdominal quinquelocular pores confined to area around vulva.....Neolecanium
   Dorsum without dense pattern of small eight-shaped pores; abdominal quinquelocular or multilocular pores occurring on anterior segments.....Toumeyella

3. Ventral submargin with numerous tubular ducts, often in a band.....4
   Ventral submargin without tubular ducts; dorsal setae slender, slightly curved, pointed; submarginal tubercles absent.....Mesolecanium

4. Legs with tibiotarsal sclerosis and free articulation; produces an ovisac.....Pulvinaria
   Legs without tibiotarsal sclerosis and free articulation (except P. persicae); produces no ovisac.....Parthenolecanium

Genus MESOLECANIUM Cockerell

Nakahara (1981) synonymized Lecanium Burmeister with Coccus Linnaeus and therefore, placed existing Nearctic species of Lecanium into several related genera. Mesolecanium was resurected to accept P. nigrofasciatum (Pergande) (formerly L. nigrofasciatum), and this is the only Nearctic species in the genus.

Mesolecanium nigrofasciatum (Pergande), 1898

Common (or Suggested) Name: terrapin scale.
Morphological Similarities: M. nigrofasciatum was a distinct species, but was often confused with some species of Parthenolecanium. M. nigrofasciatum had slender marginal setae with acute apices and lacked ventral tubular ducts.
Field Description: Adult females were about 2.0 mm in length, very convex, reddish in color with approximately 24 radiating black lines most evident near the margin. Williams and Kosztarab (1972) reported entirely red or black individuals sometimes occurred.
Habit: Adult females were found on twigs.
Distribution: (Appendix C-14).
County: Blount.
Locale: Little Greenbriar.
Elevation: 564 m.
Host(s): Platanus occidentalis L. (sycamore).
Biology: In the GSMNP, adult females were collected in October. In Virginia, mated females overwintered and produced crawlers in early spring (Williams and Kosztarab 1972). They discovered crawlers migrated to the leaves to feed and approximately 36 days later moved back to the twigs as adult females. Baker (1972) reported one generation per year.
Economic Importance: This scale was not economically important in the GSMNP. Peach growers considered this species a pest because the fruit was rendered unmarketable due to sooty molds that grew on the copious amounts of honeydew excreted by this insect (Symons and Corey 1910).
Remarks: Williams and Kosztarab (1972) noted that females in some populations encountered in both Florida and Virginia were elevated on a sclerotized base giving the females a pie-like appearance. Females from sycamore in Little Greenbriar did not exhibit this feature.

Genus NEOLECANIUM Parrott

This monotypic genus is represented by Neolecanium cornuparvum (Thro), which was collected from the GSMNP.

Neolecanium cornuparvum (Thro), 1903

Common (or Suggested) Name: magnolia scale.
Morphological Similarities: This species could be identified by the dense pattern of dorsal eight-shaped pores.
Field Description: Adult females were 8.0-13.0 mm long,

elliptical to convex, and covered with a white powdery wax. Young adult females varied from pink orange to beige (Williams and Kosztarab 1972).

Habit: The magnolia scale was collected on sapling size trees, root sprouts, and small twigs and branches.

Distribution: (Appendix C-15).

County: Blount; Cocke; Sevier.

Locale: Cades Cove Campground-Russell Field; Cherokee Orchard; Chimney Tops; Cosby Campground-Low Gap; Curry Ridge; Fighting Creek Gap-Laurel Falls; Gabes Mountain; Greenbriar Pinnacle; Grotto Falls; Hannah Mountain; Henwallow Falls; Indian Camp Creek; Porter Flat; Meigs Mountain Trail; Snake Den Trail; Sugarlands.

Elevation: 457-1646 m.

Host(s): Magnolia acuminata L. (cucumbertree); M. fraseri Walter (Fraser magnolia).

Biology: Adult females were collected in July and August in the GSMNP. Males had developed, emerged, and mated by mid-August when empty male scale covers were found. Amos (1970) found viviparous females produced crawlers in early September and first instars overwintered. He found first instars resumed growth in spring and molted twice before they matured in July and August. One generation per year was reported in Ohio (Baker 1972).

Economic Importance: Heavy populations on reproductive growth and root sprouts of Magnolia spp. were observed in the GSMNP. Reproductive capability of these trees could be affected with continued infestations. This species has not reached economically important levels at this time. Williams and Kosztarab (1972) stated that heavily infested portions of the host were weakened and sometimes resulted in the death of the branches and small trees. Large amounts of honeydew were also excreted and provided a substrate for the growth of sooty molds, attracted noxious insects, detracted ornamental value, and possibly reduced photosynthesis (Williams and Kosztarab 1972).

Remarks: This species was considered to be very common in the GSMNP. All specimens collected were taken from Magnolia spp.

Genus PARTHENOLECANIUM Sulc

Members of the genus Parthenolecanium present taxonomists with difficult species placement decisions due to host induced morphological variations (Williams and Kosztarab 1972). Adult females are heavily sclerotized at maturity that further complicate identification and study.

Key to the Species of Parthenolecanium in the GSMNP and Environs (Modified from Hamon and Williams 1984)

1. With 12 to 17 pairs of submarginal tubercles; legs with tibiotarsal scleroses.....persicae
   With less than 12 pairs of submarginal tubercles; legs without tibiotarsal scleroses.....2

2. Dorsal tubular ducts absent; marginal setae in a single irregular row; on conifers.....fletcheri
   Dorsal tubular ducts present; marginal setae in two irregular rows; on angiosperms....."corni complex"-3

3. Occurring only on Quercus spp.....quercifex
   Occurring on hosts other than Quercus spp.....corni

Parthenolecanium corni (Bouche), 1844

Common (or Suggested) Name: European fruit lecanium.
Morphological Similarities: Extreme morphological variation of P. corni occurred on different hosts. Specimens with these variations were described as separate species, P. fletcheri and P. quercifex (Cockerell 1893, Fitch 1859). Williams and Kosztarab (1972) were unable to separate these species consistently and placed them in "corni complex". They also chose not to synonymize these species until further evidence could support synonymy. Hamon and Williams (1984) gave P. fletcheri distinct species recognition based on external morphology and combined P. corni and P. quercifex.
Field Description: Adult females were variable in shape from different hosts but were generally convex, and brown. color. Females became very sclerotized at maturity.
Habit: Adult females were found on the stems and immatures were found on the undersurface of leaves.
Distribution: (Appendix C-16).
County: Blount; Cocke; Sevier; Swain, North Carolina.
Locale: Abrams Falls parking area; Andrews Bald; Boogertown, Cades Cove General Store; Chilly Spring Knob; Chimney Tops; Cosby Campground-Low Gap; Curry Ridge; Foothills Parkway; Fork Ridge; Huskey Gap; Indian Camp Creek; Junglebrook; Mount Buckley; Newfound Gap; Rainbow Falls parking area; Ramsey Cascades Trail; Sheep Pen Gap-Gregory Bald; Sugarlands; Tremont; Tuckaleechee Village; Y.
Elevation: 335-1951 m.
Host(s): Acer negundo L. (boxelder); A. pensylvanicum L. (striped maple); A. rubrum L. (red maple); A. saccharum Marshall (sugar maple); A. spicatum Lamarck (mountain maple); Betula alleghaniensis Britton (yellow birch);

Betula sp. (birch); Buxus sempervirens L. (common box); Carpinus caroliniana Walter (American hornbeam); Carya tomentosa (Poiret) Nuttall (mockernut hickory); Castanea dentata (Marshall) Borkhausen (American chestnut); Celtis occidentalis L. (hackberry); Cornus alternifolia L. f. (alternate-leaf dogwood); Crataegus sp. (hawthorn); Halesia carolina L. (Carolina silverbell); Liquidambar styraciflua L. (sweetgum); Liriodendron tulipifera L. (yellow-poplar); Morus rubra L. (red mulberry); Nyssa sylvatica Marshall (blackgum); Prunus sp. (cherry); Rubus canadensis L. (thornless blackberry); Rubus sp. (blackberry); Salix nigra Marshall (black willow); Tilia heterophylla Ventenat (white basswood); Ulmus parvifolia Jacquin (Chinese elm); Vaccinium erythrocarpum Michaux (mountain-cranberry).

Biology: Second instars overwintered on the stems of their hosts in the GSMNP. Females resumed growth in spring and deposited white eggs in May which hatched in June. Crawlers migrated to the underside of leaves where they settled and fed until late summer. Second instars migrated back to the stems before leaf drop (Williams and Kosztarab 1972). Baker (1972) reported two generations per year in Pennsylvania.

Economic Importance: This cosmopolitan species was abundant in the GSMNP. This species occurred on many hosts over a wide area, and in one instance, had adversely affected the growth of thornless blackberry over a 4.08 ha site along the south facing slope of Mt. Buckley. Further evaluation of this infestation is needed before accurate assessment of economic loss can be made. This species is primarily a pest of ornamental and shade trees (Baker 1972).

Remarks: The infestation on Mt. Buckley is the subject of a study being conducted to determine the significance and impact of this species on the vegetation of this area.

Parthenolecanium fletcheri (Cockerell), 1893

Common (or Suggested) Name: Fletcher scale.

Morphological Similarities: (See discussion on P. corni).

Field Description: Considerable variation existed with the external morphology of this species from different hosts. This species closely resembled P. corni by being extremely convex and heavily sclerotized at maturity.

Habit: One adult female was found on the stem.

Distribution: (Appendix C-17).

County: Sevier.

Locale: Boogertown.

Elevation: 396 m.
Host(s): Juniperus virginiana L. (eastern redcedar).
Biology: (See discussion of P. corni).
Economic Importance: This species was not economically important in the GSMNP. Hamon and Williams (1984) stated this species was damaging to Taxus spp.
Remarks: According to Williams and Kosztarab (1972), the Fletcher scale occurs only on hosts of Cupressaceae and Taxus spp.

Parthenolecanium persicae (Fabricius), 1776

Common (or Suggested) Name: European peach scale.
Morphological Similarities: This species was distinguished from other Parthenolecanium spp. by the presence of 12 to 17 pairs of submarginal tubercles and legs with tibio-tarsal scleroses.
Field Description: Young adult females were 5.0 mm long, 3.0 mm wide, reddish brown, oval, often with a median dorsal keel. At maturity, the females became heavily sclerotized and convex. External morphology varied considerably from different hosts (Williams and Kosztarab 1972).
Habit: Adult females were collected on the stems.
Distribution: (Appendix C-18).
County: Cocke.
Locale: Cosby Campground.
Elevation: 640 m.
Host(s): Pyracantha sp. (firethorn).
Biology: Adult females were observed in August in the GSMNP. The life history of this species was similar to the European fruit lecanium, P. corni. Marchal (1908) reported that this species exhibited bisexual and facultative parthenogenesis and this information was supported by infestations sampled by Williams and Kosztarab (1972).
Economic Importance: This species was not economically important in the GSMNP. P. persicae is primarily a pest of ornamentals and will eventually kill the host if not controlled (Williams and Kosztarab 1972).
Remarks: In the GSMNP, this species was collected from an ornamental planting of Pyracantha. The importance of this species to the GSMNP is considered minimal since few of its hosts are represented in the GSMNP.

Parthenolecanium quercifex (Fitch), 1859

Common (or Suggested) Name: oak lecanium.
Morphological Similarities: (See P. corni).

Field Description: This species resembled P. corni but the anterior and posterior ends of most specimens were tapered and two humps were present mid-dorsally (Hamon and Williams 1984).
Habit: Adult females were found on the twigs and branches.
Distribution: (Appendix C-19).
County: Blount; Cocke; Sevier.
Locale: Cosby Campground; Foothills Parkway; Gabes Mountain Trail; Greenbriar Ranger Station; Sinks; Tremont; Trilium Gap Trailhead.
Elevation: 274-793 m.
Host(s): Quercus alba L. (white oak); Q. prinus L. (chestnut oak); Q. rubra L. (northern red oak); Q. stellata Wangenheim (post oak).
Biology: (See discussion of P. corni).
Economic Importance: P. quercifex was not economically important in the GSMNP. Sanders (1909) reported that this species damaged oaks in the south Atlantic and Gulf states.
Remarks: Hamon and Williams (1984) found P. quercifex only on oaks in Florida but Williams and Kosztarab (1972) listed many non-Quercus hosts in Virginia.

Genus PULVINARIA Targioni-Tozzetti

Of nine species known to occur in North America, two species, P. acericola (Walsh and Riley) and P. innumerabilis (Rathvon), occurred in the GSMNP. These two species are similar and can be separated by the type of marginal setae (Williams and Kosztarab 1972). The setae of P. acericola were slender and curved with bifid and fimbriate apices, and the setae of P. innumerabilis were stout, straight, and had blunt apices.

Pulvinaria acericola (Walsh and Riley), 1868

Common (or Suggested) Name: cottony maple leaf scale*.
Morphological Similarities: P. acericola can be distinguished from other North American Pulvinaria spp. by the presence of ten-locular pores on the ventral abdomen, acute-bifid-fimbriate marginal setae, and submarginal tubercles.
Field Description: Adult females were 2.5-4.0 mm long, oval, convex, and brown to red. At maturity, the females produced a cottony ovisac two to three times longer than the body of the female and ribbed longitudinally (Williams and Kosztarab 1972).
Habit: Adult females were found only on the leaves.
Distribution: (Appendix C-20).

County: Blount; Sevier.
Locale: Boogertown; Cades Cove.
Elevation: 396 m, 549 m.

Host(s): Acer negundo L. (boxelder); A. rubrum L. (red maple).

Biology: Adult females with ovisacs were found on leaves in July and immatures were found in late July and August on the leaves. Immatures migrated to the stems in autumn before leaffall where they overwintered. In spring, the immature females migrated to the leaves where they matured and mated (Baerg 1947).

Economic Importance: Williams and Kosztarab (1972) and Baerg (1947) reported death of twigs and branches and occasionally entire trees due to infestations of the cottony maple leaf scale. This species was of no economic importance in the GSMNP.

Remarks: P. acericola is continually confused with P. innumerabilis which also produces a cottony ovisac on Acer spp. Females of P. innumerabilis settled on the stem and produced ovisacs while females of P. acericola settled on the undersurface of leaves and produced ovisacs. Morphologically, the two species were distinct and their differences were described by Howard (1898, 1900).

Pulvinaria innumerabilis (Rathvon), 1854

Common (or Suggested) Name: cottony maple scale.

Morphological Similarities: P. innumerabilis could be distinguished from other Pulvinaria spp. by having stout, straight, marginal setae with blunt apices.

Field Description: Adult females were 4.0-7.0 mm long, 2.0-5.0 mm wide, convex, and oval. Color was extremely variable (Kosztarab and Williams 1972), but specimens from the GSMNP were uniformly brown. Eggs were deposited in a cottony ovisac produced posterio-ventrally that raised this portion of the scale off the host.

Habit: Adults were found only on the stems, and immatures were found on stems and the undersurface of leaves.

Distribution: (Appendix C-21).
County: Blount; Cocke; Sevier.
Locale: Boogertown; Cherokee Orchard; Cosby Creek; Glades; Indian Camp Creek; Junglebrook; Low Gap; Foothills Parkway; Rainbow Falls parking area; Tremont.
Elevation: 396-976 m, 1281 m.

Host(s): Acer negundo L. (boxelder); A. rubrum L. (r maple); Carpinus caroliniana Walter (American hornbeam); Liriodendron tulipifera L. (yellow-poplar);

Nyssa sylvatica Marshall (blackgum); Rhus copallina L. (shining sumac); Tilia heterophylla Ventenat (white basswood).

Biology: In the GSMNP, adult females with ovisacs were found in May. Putnam (1880) reported the life cycle of this species closely followed the development of the cottony maple leaf scale, with two major differences. Males of the cottony maple leaf scale emerged and mated with females in the spring and adult females produced ovisacs on the leaves. Males of the cottony maple scale emerged and mated with females in the fall and adult females produced ovisacs while on the stems of the host. If mated, the females of the cottony maple scale overwintered gravid. Unmated females produced only male progeny in the spring (Phillips 1962).

Economic Importance: Occasional outbreaks have occurred but seem to be controlled by simultaneous population increases of parasitoids and predators (Williams and Kosztarab 1972). No economic damage was observed in the GSMNP.

Remarks: This species was common in the GSMNP and considered cosmopolitan throughout North America by Williams and Kosztarab (1972).

Genus TOUMEYELLA Cockerell

Toumeyella contains five species in the United States and two species, T. liriodendri (Gmelin) and T. pini (King), occurred in the GSMNP. T. liriodendri could be distinguished by the presence of discoidal pores that extended anteriorly to above the rostrum and occurred on non-coniferous hosts. T. pini had discoidal pores restricted to the posterior body and occurred on coniferous hosts (Williams and Kosztarab 1972).

Toumeyella liriodendri (Gmelin), 1789

Common (or Suggested) Name: tuliptree scale.

Morphological Similarities: The tuliptree scale had five-locular pores on the ventral abdomen and was easily distinguished from other Toumeyella spp. on non-coniferous hosts.

Field Description: Adult females were 3.0-6.6 mm long, convex, reddish-brown and mottled with light red streaks.

Habit: Adults and immatures were found on the stems.

Distribution: (Appendix C-22).

County: Blount; Sevier.

Locale: Glades; Oconaluftee Ranger Station; Proffits General Store; Rabbit Creek.

Elevation: 381-518 m, 625 m.
Host(s): Liriodendron tulipifera L. (yellow-poplar).
Biology: This univoltine species produced crawlers in August to September in the GSMNP. Second instars overwintered and resumed growth in the spring. Over 3000 crawlers may be produced by one female during her lifetime (Burns and Donley 1970). Simpson and Lambdin (1983) reported the life history of this species, including parasitoids and predators, in Tennessee.
Economic Importance: Infestation increased rapidly due to the high reproductive capacity of this species and the habit of ants protecting the scales from parasitoids and predators (Burns and Donley 1970). Large amounts of honeydew excreted by this species provided a substrate for the growth of sooty molds which attracted noxious insects and hindered photosynthesis. Burns and Donley (1970) reported mortality of sapling size trees as a result of heavy infestations. Infestations in and near the GSMNP occurred on trees in disturbed habitats only and did not affect forest specimens.
Remarks: This species could be an important factor in the future composition of the cove hardwood forest since its host, yellow-poplar, occurred in pure stands and was one of the most abundant and dominant trees in the cove hardwood, hemlock, and closed oak forests of the GSMNP (Stupka 1964).

Toumeyella pini (King), 1901

Common (or Suggested) Name: striped pine scale.
Morphological Similarities: T. pini had been confused with T. parvicornis (Cockerell) because of mixed infestations (Williams and Kosztarab 1972). Ferris (1920) synonymized the two species but Williams and Kosztarab (1972) recognized distinct differences between the species. T. pini was distinguished by having discoidal pores only on the posterior portion of the body.
Field Description: Adult females were 6.0-7.0 mm long, convex, and reddish brown.
Habit: Adult females were found on the stems and new growth.
Distribution: (Appendix C-23).
County: Blount.
Locale: Scott Mountain.
Elevation: 1021 m.
Host(s): Pinus rigida Miller (pitch pine).
Biology: Little life history information for this species is available. In Virginia, Williams and Kosztarab (1972) reported crawlers in May that preferred to settle on new growth. Adult females were found in

September in the GSMNP.

Economic Importance: The economic importance of this species is unknown. A heavy infestation was found on Scott Mountain on regeneration of pitch pine and could adversely affect growth of this stand.

Remarks: This species has been recorded only from hosts in the genus Pinus (Williams and Kosztarab 1972).

Family DIASPIDIDAE Ferris

The Diaspididae, or armored scale insects are the largest and most diverse group of Coccoidea in the world. Over 1700 species have been described in 85 genera (Nakahara 1982). In the United States, approximately 300 species are known from 81 genera (Davidson et al. 1974). A large number of these scales cause great economic loss to fruit crops, cultivated greenhouse and landscape plants, and forest and shade trees (Baker 1972, Dekle 1976).

Adult females are membranous, resemble integumental sacks, and can be recognized morphologically by the fusion of the posterior abdominal segments into the compound pygidium and a simple anal opening. Adult females also lack abdominal spiracles, possess tubular ducts without lateral filaments, one segmented antennae, and the legs are absent or vestigial (Ferris 1937).

Thirty species representing 11 genera were collected from the GSMNP from a wide range of host plants. All species in the GSMNP belong to the subfamily Diaspidinae and can be separated into two tribes, the Aspidiotini and the Diaspidini. The aspidiotine females are normallly pear-shaped or rounded with macroducts of the one-barred type, second pygidial lobes not bilobed, fimbriate plates usually present, one seta on the antennae, and normally circular scale covers (Kosztarab 1963). The diaspidine females are elongated and normally have macroducts of the two-barred type, second pygidial lobes bilobed, gland spines present rather than fimbriate plates, two or more setae on the antennae, and elongated scale covers (Kosztarab 1963).

TRIBE ASPIDIOTINI

Key to the Genera of the Tribe Aspidiotini in the GSMNP and Environs (Modified from Kosztarab 1963)

1. Three paraphyses in the space between the second and third lobes.....2
   No more than two paraphyses between the second and third lobes.....3

2. Pygidium tapering to an acute apex; three pairs of lobes present; perivulvar pores in four groups.....Acutaspis
Pygidium not tapering to an acute apex; four pairs of lobes present, fourth lobe indicated by a sclerotized point; perivulvar pores lacking, or in five small groups.....Melanaspis

3. Median and second lobes well developed, sclerotized, apically rounded, their axes somewhat diagonal, so that the lobes seem to converge slightly.....Quadraspidiotus
Not so; if more than the median lobes are present the axes are parallel.....4

4. Second lobe never developed as more than a mere sclerotized point; anal opening normally small and well toward the apex of the pygidium, although at times larger; plates usually small, at times scarcely developed.....Diaspidiotus
Second lobe usually and the third lobe at times developed, although in some species neither is more than a point; anal opening conspicuously large; plates usually well developed; 5

5. Second lobes usually present, smaller than the median lobes (except some specimens of Abgrallaspis howardi and A. townsendi); anal opening diameter usually less than the length of the median lobes, and usually removed two or more times its diameter from the median lobes.....Abgrallaspis
Second lobes absent, replaced by hyaline points, anal opening as large or larger than the length of the median lobes.....Hemiberlesia

Genus ABGRALLASPIS Balachowsky

Abgrallaspis consists of 14 North American species of which 10 are recorded from the United States (Miller and Howard 1981). A complex of species involving A. howardi (Cockerell) caused much confusion among taxonomists and this situation remains unresolved. Four species were collected from the GSMNP.

Key to the Species of Abgrallaspis in the GSMNP and Environs (Modified from Davidson 1964)

1. Second pygidial lobes much shorter than median pygidial lobes.....2
Second pygidial lobes as long or longer than median pygidial lobes.....comstocki

2. Submarginal ducts occasionally present on abdominal segment four; normally less than 20 macroducts present; not on conifers.....3
   Submarginal dorsal macroducts always present on abdominal segments three and four; normally more than twenty macroducts present; on conifers.....ithacae
3. Median lobes arising vertically from the pygidial apex, about as wide as long, widely separated, not obscuring the plates between them.....townsendi
   Median lobes convergent, longer than wide, closely appressed often obscuring the median pair of plates.....howardi

Abgrallaspis comstocki (Johnson), 1896

Common (or Suggested) Name: Comstock scale*.
Morphological Similarities: A. comstocki was morphologically close to A. howardi (Cockerell) and A. townsendi (Cockerell). The degree of development of the second pygidial lobes was the primary basis for species separation. The Comstock scale had second lobes that were as long or longer than the median pydigial lobes while the second lobes of A. howardi and A. townsendi were shorter than the median lobes.
Field Description: The test of the female was approximately 1.5 mm in diameter, circular, buff colored, with a yellowish submarginal exuviae.
Habit: Adult females were collected from the leaf surfaces.
Distribution: (Appendix C-24).
County: Sevier.
Locale: Little Greenbriar; Ramsey Cascades; Wears Road.
Elevation: 457-473 m, 884 m.
Host(s): Acer pensylvanicum L. (striped maple); Cornus florida L. (flowering dogwood); Nyssa sylvatica Marshall (blackgum).
Biology: Little life history information for this species was known, but collections from Nyssa and Cornus are new host records.
Economic Importance: No economically important infestations were observed in the GSMNP.
Remarks: Accurate host records are required to aid in identification of this species. A. comstocki was recorded primarily from Acer spp. while A. howardi and townsendi were collected from other host groups. Stannard (1965) suggested that this species was the leaf form of Diaspidiotus ancylus (Putnam) but Miller and Howard (1981) retained A. comstocki with species rank until further studies were completed. Host records in this study indicated the possibility of dimorphic species or new host records.

Abgrallaspis howardi (Cockerell), 1895

Common (or Suggested) Name: Howard scale*.
Morphological Similarities: Davidson's (1964) detailed analysis of Abgrallaspis compared morphologies of related species based on host transfer studies. Genetically produced aberrant forms of A. howardi existed and taxonomic separation from A. townsendi was difficult. Identification was based on the development of the second pygidial lobes and host records.
Field Description: The test of the female was 1.7 mm in diameter, circular, white, with a golden subcentral exuviae (Dekle 1976).
Habit: Adult females were found only on the twigs.
Distribution: (Appendix C-25).
County: Blount; Cocke.
Locale: Cosby Campground; Rabbit Creek; Wears Road; Y.
Elevation: 335-701 m.
Host(s): Cornus florida L. (flowering dogwood); Liquidambar styraciflua L. (sweetgum); Robinia pseudoacacia L. (black locust).
Biology: Little life history information was available. Ferris (1938) and Dekle (1976) reported this species infested leaves of the host plant. Collections of adult females from the GSMNP were taken from twigs in August. This species was polyphagous.
Economic Importance: No economic damage has been reported for this species and no damage was observed in the GSMNP.
Remarks: The Howard scale was originally described from plum in Colorado and hosts of the family Rosaceae were preferred (Ferris 1938). This species is distributed primarily in the western United States but range and host expansion has occurred to the eastern and southern United States (Dekle 1976).

Abgrallaspis ithacae (Ferris), 1938

Common (or Suggested) Name: hemlock scale*.
Morphological Similarities: A. ithacae was sometimes confused with A. townsendi but the latter did not develop on Coniferales, the only known host group for the former.
Field Description: Scale of the adult female was 1.1-1.7 mm long, 1.1-1.3 mm wide, oval, light to dark brown, with central exuviae. The scale covering of the first instar was white. Females often incorporated epidermal layers of the host leaf into construction of the scale cover. This behavior disguised the female from possible detection by parasitoids and predators.

Habit: All stages of development were collected on the undersides of the needles.
Distribution: (Appendix C-26).
County: Blount; Cocke; Sevier.
Locale: Abrams Falls parking area; Abrams Falls; Boogertown; Bote Mountain Trailhead; Cades Cove; Cosby Campground; Cosby Creek; Curry Ridge; Elkmont; Emerts Cove; Gabes Mountain Trail; Glades; Greenbriar Ranger Station; Grotto Falls; Hannah Mountain-Sheep Pen Gap; Indian Camp Creek; Junglebrook; Low Gap; Little Greenbriar School; Meigs Mountain Trail; Pine Oak Trail; Rabbit Creek; Ramsey Cascades; Sinks; Sugarlands; Tremont-Camp Townsend; Tremont Trail; Trilium Gap Trail; Y.
Elevation: 335-1250 m.
Host(s): Tsuga canadensis (L.) Carriere (eastern hemlock).
Biology: Adult females were found in May and June and first instars were found in late June in the GSMNP. Kosztarab's (1963) data showed that second instars were present during October in Ohio. Stoetzel (1976) reported two generations per year in Maryland.
Economic Importance: This species was not economically important in the GSMNP. However, this species was reported to cause premature leaf abscission and mortality of young trees (Pirone 1970, Wescott 1974).
Remarks: Hosts of this species were restricted to the genera Abies, Pseudotsuga, and Tsuga. Abies and Tsuga occurred in the GSMNP, but collections were taken from Tsuga only. This species was the second most commonly collected scale insect in the GSMNP, and was considered to be abundant and cosmopolitan throughout the park.

Abgrallaspis townsendi (Cockerell), 1896

Common (or Suggested) Name: Townsend scale*.
Morphological Similarities: Ferris (1938) synonymized this species with A. howardi due to the similarities of the median pygidial lobes. Host transfer studies conducted by Davidson (1964) established A. townsendi as a valid species. Intermediate forms with reduced lobes resembled Diaspidiotus ancylus and forms with lengthened lobes resembled A. comstocki. However, both Davidson (1964) and Miller and Howard (1981) considered this species valid until further research indicated differently.
Field Description: The scale cover of the female was 1.5 mm in diameter, circular, white-grayish white, with a central or subcentral orange exuviae (Dekle 1976).
Habit: Adult females were collected on the main stem.
Distribution: (Appendix C-27).

County: Blount; Sevier.
Locale: Wears Road; Y.
Elevation: 366-457 m.

Host(s): Cornus florida L. (flowering dogwood).

Biology: Specimens of adult females were collected in August from the stem although Dekle (1976) reported this species occurred on both stem and leaves of the host. Kosztarab (1963) stated this species overwintered as adult females in Ohio.

Economic Importance: This species was not economically important in the GSMNP.

Remarks: Adult females of this species, A. howardi and one specimen labeled A. poss. comstocki (Nakahara 1977), were collected concurrently on the same tree. Host induced variation in Abgrallaspis has been reported (Davidson 1964) and the possibilty of sibling species has been suggested (Miller and Howard 1981). Knipscher's et al. (1976) studies on morphological differences between bark and leaf forms of Chionaspis nyssae Comstock confirmed the presence of sibling species among two previously recognized species of Diaspididae. However, further host transfer studies and morphological comparisons with the Abgrallaspis complex must be made before these species can be synonymized or regarded as dimorphic.

Genus ACUTASPIS Ferris

Members of this genus are primarily Neotropical and recorded from the foilage of Coniferales. A. morrisonorum Kosztarab was the only species recorded from the GSMNP.

Acutaspis morrisonorum Kosztarab, 1963

Common (or Suggested) Name: round conifer scale*.

Morphological Similarities: A. morrisonorum was recognized by the presence of three pairs of pygidial lobes with three paraphyses between the second and third pydigial lobes, perivulvar pores in four groups, and the pygidium tapering into an acute apex.

Field Description: Scale of the female was slightly oval, 1.5 mm long, 1.25 mm wide, yellowish-brown with a central exuviae (Kosztarab 1963). Scales from the GSMNP were dark brown and slightly convex.

Habit: Adult females were collected from the upper leaf surface of the host plant.

Distribution: (Appendix C-28).
County: Sevier.
Locale: Sugarlands.
Elevation: 457 m.

Host(s): Tsuga canadensis (L.) Carriere (eastern hemlock).
Biology: Adult females were collected in early August in the GSMNP. Kosztarab (1963) reported this species overwintered as second instars in Ohio.
Economic Importance: This species was not economically important in the GSMNP.
Remarks: This species was collected from an open semi-disturbed area near the Sugarlands Visitor Center and has been recorded from hosts in Coniferales only.

Genus Diaspidiotus Leonardi

Many members of this genus are polyphagous and considered to be important plant pests (Baker 1972, Davidson et al. 1974, Dekle 1976). Of twelve species represented in North America (Nakahara 1982), four species were collected from the GSMNP.

Key to the Species of Diaspidiotus in the GSMNP and Environs (Modified from Kosztarab 1963)

1. Perivulvar pores present.....2
   Perivulvar pores absent; on sweetgum.....liquidambaris

2. Plates small, not fimbriated; daggerlike;.....osborni
   Plates large and well fimbriated.....3

3. Axis of median lobes relatively parallel, notched once on lateral margins; two small plates between median lobes.....ancylus
   Axis of median lobes relatively divergent, notched on both lateral and medial margins; no plates between median lobes.....uvae

Diaspidiotus ancylus (Putnam), 1878

Common (or Suggested) Name: Putnam scale.
Morphological Similarities: The Putnam scale could be easily confused with D. uvae (Comstock). The median lobes of D. ancylus were smaller with parallel axes and D. uvae had larger median lobes with divergent axes. Ferris (1938) indicated this species was morphologically unstable because of its variable forms and hesitated to discuss its validity.
Field Description: The scale of the female was 1.4-1.8 mm long, 1.1-1.5 mm wide, circular, flat to slightly convex, dark gray with a subcentral to central golden exuviae. The scale of the male was 1.2 mm long, 1.1 mm wide, gray, noncarinate, with a subterminal golden

exuviae.

Habit: All stages were found on the bark, under peeling bark flakes, on twigs and small branches.

Distribution: (Appendix C-29).

County: Blount; Cocke; Sevier.

Locale: Boogertown; Chimney Tops; Cosby Campground; Emerts Cove; Greenbriar; Indian Camp Creek; Meigs Mountain Trail; Sheep Pen Gap; Snake Den Trail; Spence Field-Russell Field.

Elevation: 396-518 m, 710-762 m, 1342-1646 m.

Host(s): Acer negundo L. (boxelder); Betula alleghaniensis Britton (yellow birch); B. lenta L. (sweet birch); Carpinus caroliniana Walter (American hornbeam); Halesia carolina L. (Carolina silverbell); Platanus occidentalis L. (sycamore); Robinia pseudoacacia L. (black locust); Tilia heterophylla Ventenat (white basswood).

Biology: Adult females were collected in June and July. Males had emerged by July. Conflicting evidence regarding the number of generations per year has been reported (Baker 1972, Michelbacher and Ortega 1958) in North America but Baker reported one generation per year and immatures overwintered. Adult females on yellow birch in the GSMNP had parasitoid emergence holes in 40% of the exuviae.

Economic Importance: No economically important infestations were observed in the GSMNP. Baker (1972) listed numerous hosts for this species and stated that heavy infestations would eventually kill twigs and branches.

Remarks: Specimens from B. alleghaniensis closely resembled Diaspidiotus osborni (Newell and Cockerell) by having reduced and only slightly fimbriated plates. Kosztarab (1963) stated that specimens labeled as D. ancylus from Ohio showed extreme variation and more than one species may be involved. Kosztarab also examined material from B. lutea var. allegheniensis (Britton) Ashe (=B. alleghaniensis Britton) in Virginia and stated that specimens were "close to the typical specimens". GSMNP specimens from Betula did not resemble the "typical" specimens which Kosztarab described. Stannard (1965) believed this species was trimorphic, the two additional forms being Abgrallaspis comstocki and A. howardi. This view was not accepted among taxonomists and these species of Abgrallaspis were retained as valid. This species was considered common in the GSMNP.

Diaspidiotus liquidambaris (Kotinsky), 1903

Common (or Suggested) Name: sweetgum scale*.

Morphological Similarities: D. liquidambaris was easily recognized by the lack of perivulvar pores and the highly fimbriated plates.

Field Description: Scales of females were 0.8-1.2 mm in diameter, circular, white, flat, with subcentral exuviae. Feeding by this species caused the formation of leaf galls on the upper surface of infested leaves surrounded by a chlorotic circular ring.

Habit: Females were found on the stems and leaves of the host.

Distribution: (Appendix C-30).
County: Blount; Cocke; Sevier.
Locale: Bote Mountain trailhead; Cades Cove; Chilly Spring Knob; Emerts Cove; Gabes Mountain trailhead; Greenbriar; Little River Gorge; Sugarlands; Tremont; Trilium Gap Trail; Y.
Elevation: 335-610 m, 915 m.

Host(s): Liquidambar styraciflua L. (sweetgum).

Biology: Kosztarab (1963) stated that unmated adult females and pupal males overwintered and all eggs had hatched by mid-June. Crawlers migrated to the undersides of leaves where they settled to feed. On hosts in the GSMNP and elsewhere, gall formation was induced on the upper surface of the leaves caused by feeding of this species. D. liquidambaris was bivoltine and was one of two leaf gall-forming diaspidids that are recorded from the United States (Miller and Howard 1981).

Economic Importance: No economically important infestations were observed in the GSMNP. Dekle (1976) regarded this species as an occasional pest in Florida and Baker (1972) reported this species to be an important nursery pest in Missouri.

Remarks: Dekle (1976) and Kosztarab (1963) reported the sweetgum scale to be host specific, but Ferris (1938) stated this species had been collected from maple in Florida and Washington D. C.

Diaspidiotus osborni (Newell and Cockerell), 1898

Common (or Suggested) Name: Osborn scale*.

Morphological Similarities: D. osborni was distinguished from other Diaspidiotus spp. by the lack of dorsal macroducts anterior to the fifth abdominal segment and with simple daggerlike plates on both the pygidial margin and between the pygidial lobes.

Field Description: Scale of the females was 1.1-1.5 mm in diameter, circular, white to beige, often the color of the plant tissue it infested. The yellow exuviae was subcentral. The scale of the male was 0.7 mm long, 0.5 mm wide, beige, with a subcentral gray exuviae.

Habit: Adult females were collected from the twigs, bark and main trunk.
Distribution: (Appendix C-31).
County: Blount; Cocke; Sevier.
Locale: Cosby Campground; Craig Cove; Huskey Gap; Tuckaleechee Village.
Elevation: 335 m, 412 m, 701 m, 793 m.
Host(s): Acer rubrum L. (red maple); Castanea dentata (Marshall) Borkhausen (American chestnut); Cornus florida L. (flowering dogwood).
Biology: Kosztarab (1963) stated most eggs had hatched by early July in Ohio and Stoetzel (1976) reported adult females overwintered and developed through two generations per year in Maryland. Adult females were collected during late July to early August in the GSMNP.
Economic Importance: This species was not economically important in the GSMNP.
Remarks: Specimens collected from yellow birch were morphologically very close to this species, but had slightly more developed and fimbriated plates than the typical concept of D. osborni (Ferris 1938). The Osborn scale has been collected from Betula spp. (Kosztarab 1963) and this species is possibly a phenotypic variation of D. ancylus.

Diaspidiotus uvae (Comstock), 1881

Common (or Suggested) Name: grape scale.
Morphological Similarities: This species closely resembled D. ancylus, but could be separated by the size and shape of the median lobes (See D. ancylus).
Field Description: Scale of the female was 1.2-1.5 mm in diameter, circular, flat, yellow with a golden central exuviae.
Habit: Adult females were found on the vine.
Distribution: (Appendix C-32).
County: Blount.
Locale: Tremont.
Elevation: 427 m.
Host(s): Vitis sp. (grape).
Biology: Adult females were found in August from the GSMNP. Kosztarab (1963) found adult females overwintered in Ohio and produced crawlers in May and June and developed through one generation per year.
Economic Importance: This species was not economically important in the GSMNP.
Remarks: Ferris (1938) viewed D. uvae with skepticism due to the morphological similarities with D. ancylus, but based on material he observed and the unique host

association of D. uvae with Vitis spp., he regarded this species to be valid.

Genus Hemiberlesia Cockerell

This genus is represented in North America by seven species. Only H. diffinis (Newstead) was recorded from the GSMNP.

Hemiberlesia diffinis (Newstead), 1893

Common (or Suggested) Name: diffinis scale*.
Morphological Similarities: H. diffinis could be recognized by the sclerotized second and third pygididal lobes with a deep lateral notch on the second lobes.
Field Description: Scale of the female was 1.3 mm long (Dekle 1976), oval to elongate, highly convex, white to gray, with a subterminal exuviae.
Habit: Adult females were collected from the twigs.
Distribution: (Appendix C-33).
County: Sevier.
Locale: Charlie's Bunion.
Elevation: 1616 m.
Host(s): Betula lenta L. (sweet birch).
Biology: Adult females were collected in June from the GSMNP. Second instars were reported to overwinter (Stoetzel 1976).
Economic Importance: This species was not economically important in the GSMNP.
Remarks: H. diffinis was originally described from an undetermined host in British Guiana, S.A. (Newstead 1893), but Ferris (1938) believed it to be a native of North America.

Genus Melanaspis Cockerell

Deitz and Davidson (1986) provided a synopsis of 35 North American Melanaspis spp. and included biological information for many species. Of fifteen Melanaspis species recorded from the United States (Nakahara 1982), Melanaspis obscura (Comstock) was the only species recorded from the GSMNP.

Melanaspis obscura (Comstock), 1881

Common (or Suggested) Name: obscure scale.
Morphological Similarities: The obscure scale was easily recognized by the presence of four pygidial lobes with three paraphyses between them, and perivulvar pores in

four groups.

Field Description: Scale of the female was 2.0-3.0 mm in diameter, circular, convex, gray to dark gray, with a central to subcentral black exuviae surrounded by a white ring.

Habit: Adult females were found encrusted on the twigs and small branches.

Distribution: (Appendix C-34).
County: Blount.
Locale: Y.
Elevation: 366 m.

Host(s): Quercus alba L. (white oak).

Biology: Stoetzel and Davidson (1971) reported that second instar males and females overwintered in Maryland on red oaks. Mating occurred in May followed by egg production and hatching in July. Development on white oaks was different than on red oaks, and Stoetzel and Davidson (1973) believed these two populations represented sibling species. In contrast to Stoetzel and Davidson's (1973) studies, second instars were found in August in the GSMNP on white oak.

Economic Importance: The obscure scale was one of the most serious pests of shade trees throughout the United States (Dekle 1976, Kosztarab 1963, Nixon 1968, Stoetzel and Davidson 1971). Dieback of infested ornamental plantings has been reported, but damage to forest specimens has not been observed (Deitz and Davidson 1986).

Remarks: Several limbs of an infested white oak in the GSMNP were killed by this species, but the tree was located adjacent to a major road in an area where disturbance by heavy visitor vehicle and foot traffic occurred.

Genus Quadraspidiotus MacGillivray

This genus is represented in the United States by nine species. Several species are important economically in orchards and ornamental plantings (Craighead 1950, Dekle 1976, Kosztarab 1963). Three species were collected from the GSMNP.

Key to the Species of Quadraspidiotus in the GSMNP and Environs (Modified from Kosztarab 1963)

1. Perivulvar pores present.....2
   Perivulvar pores absent.....perniciosus

2. Third lobes indicated by at least a point; mesal paraphysis of first interlobular space not strongly swollen apically.....juglansregiae

Third lobes entirely absent; mesal paraphysis of first interlobular space strongly swollen apically, clublike.....forbesi

Quadraspidiotus forbesi (Johnson), 1896

Common (or Suggested) Name: Forbes scale.
Morphological Similarities: Q. forbesi was distinguished from other GSMNP Quadraspidiotus by the presence of perivulvar pores and third pygidial lobes absent.
Field Description: Scale of female was 1.0-2.0 mm in diameter, flat to slightly convex, with an orange subcentral to marginal exuviae.
Habit: Females were collected from twigs and bark on the trunk.
Distribution: (Appendix C-35).
County: Cocke; Sevier.
Locale: Cherokee Orchard; Cosby Campground.
Elevation: 701 m, 838 m.
Host(s): Robinia pseudoacacia L. (black locust); Malus sylvestris (L.) Miller (apple).
Biology: Kosztarab (1963) reported one generation per year in Ohio. He also found that apterous males emerged in mid-April and eggs hatched in July. Second instars were collected during August in the GSMNP.
Economic Importance: This species was not economically important in the GSMNP, but Kosztarab (1963) reported this species was an occasional pest in Ohio orchards.
Remarks: This species is polyphagous and cosmopolitan throughout the United States (Nakahara 1982) and had a limited distribution in the GSMNP.

Quadraspidiotus juglansregiae (Comstock), 1881

Common (or Suggested) Name: walnut scale.
Morphological Similarities: Q. juglansregiae was easily recognized by the prominent marginal constrictions between thoracic segments.
Field Description: The scale of the female was 1.5-2.5 mm in diameter, circular, slightly convex, light gray, with a subcentral exuviae.
Habit: Females and males were found on the twigs and smaller branches.
Distribution: (Appendix C-36).
County: Blount; Cocke.
Locale: Cosby Campground; Polecat Ridge.
Elevation: 640 m, 701 m.
Host(s): Acer pensylvanicum L. (striped maple); Robinia pseudoacacia L. (black locust).

Biology: This bivoltine species overwintered as second instars that matured and mated in late March (Simpson 1976) in the GSMNP and other localities in Tennessee.
Economic Importance: No economic damage was observed in the GSMNP, but infestations in urban areas increased rapidly and seriously injured trees, particularly flowering dogwood (Lambdin 1987b).
Remarks: This species was considered to be rare in the GSMNP. Collection records from USDA indicated a general and cosmopolitan distribution in the United States but Ferris (1938) stated that its European distribution and similarity to the European Q. ostreaeformis (Curtis) did not allow accurate assessment of its origination.

Quadraspidiotus perniciosus (Comstock), 1881

Common (or Suggested) Name: San Jose scale.
Morphological Similarities: The San Jose scale could be recognized by the lack of perivulvar pores, and large apically bifid plates anterior to the third pygidial lobes.
Field Description: Scale of the female was 1.5-2.0 mm in diameter, circular, light brown to dark gray, slightly convex, with a yellow subcentral exuviae.
Habit: All stages of females were found on the twigs, branches, and main stem.
Distribution: (Appendix C-37).
County: Cocke.
Locale: Cosby Campground.
Elevation: 701 m.
Host(s): Malus sylvestris (L.) Miller (apple).
Biology: Only dead adult females were collected in the GSMNP. One or more generations per year in Oregon (Schuh and Mote 1948) to five generations per year in Missouri (Haseman and Sullivan 1923) were reported. Kosztarab (1963) stated the species overwintered as second instars.
Economic Importance: This species was not observed to be economically important in the GSMNP. Historically, this species was regarded as the most important shade tree pest in the United States (Craighead 1950) and was considered a serious pest of fruit trees in Florida (Dekle 1976).
Remarks: This species was introduced from Asia (Ferris 1938).

TRIBE DIASPIDINI

Key to the Genera of the Tribe Diaspidini in the GSMNP and Environs (Modified from Kosztarab 1963)

1. Median lobes united basally, zygotic.....Chionaspis
   Median lobes not united basally, nonzygotic.....2

2. Body pear-shaped or almost circular; without gland tubercles on margin of anterior abdominal segments.....Carulaspis
   Body elongated, often spindle-shaped; with gland tubercles on margin of anterior abdominal segments....3

3. Dorsal median pygidial furrow present; median lobes close together, and without gland spines between them.....Unaspis
   Dorsal median pygidial furrow absent; median lobes farther apart, with two gland spines between them.....4

4. Dorsal pygidial ducts distributed irregularly; antennae associated with unusual sclerotic tubercles..Velataspis
   Dorsal pygidial ducts arranged in definite segmental rows; antennae not associated with unusual sclerotic tubercles.....Lepidosaphes

Genus CARULASPIS MacGillivray

Only two species are known from this genus in North America. Carulaspis juniperi (Bouche) was collected from the GSMNP.

Carulaspis juniperi (Bouche), 1851

Common (or Suggested) Name: juniper scale*.
Morphological Similarities: C. juniperi was recognized by the pear-shaped body and the dorsal macroduct between the median lobes.
Field Description: Scale of the female was 1.0-1.5 mm long, circular, convex, white, with a yellow subcentral exuviae.
Habit: Adult females were found on the leaves.
Distribution: (Appendix C-38).
County: Blount; Cocke; Sevier.
Locale: Boogertown; Cosby Campground; Tuckaleechee Village; Wears Road.
Elevation: 335-701 m.
Host(s): Juniperus virginiana L. (eastern redcedar).
Biology: Kosztarab (1963) reported mature females

overwintered, crawlers appeared in June, and males emerged from July until August in Ohio. Adult females were observed during August in the GSMNP.

Economic Importance: This species was not economically important in the GSMNP although Pirone (1970) reported C. juniperi was a common pest on Juniperus spp.

Remarks: The distribution of this species was restricted due to the limited distribution of its host. This was an introduced species originally described from specimens on mistletoe from Europe.

Genus Chionaspis Signoret

In 1967, Takagi and Kawai clarified taxonomic confusion between Chionaspis and the related genus Phenacaspis by presenting arguments that established Phenacaspis as a junior synonym of Chionaspis. Thus, all species of Phenacaspis were transferred to Chionaspis or Pseudaulacaspis MacGillivray. Most species of Phenacaspis were shown to be dimorphic forms of corresponding Chionaspis species, and Knipscher et al. (1976) provided the first biosystematic evidence that showed a species of Chionaspis, Chionaspis sylvatica Sanders, was the bark form of C. nyssae Comstock.

In North America, Chionaspis is widely distributed and well represented, especially east of the Rocky Mountains (Ferris 1937). Of twenty species recorded from the United States (Nakahara 1982), eleven species were collected from the GSMNP.

Key to the Species of Chionaspis of the GSMNP and Environs (Modified from Liu et al. 1988)

1. Median lobes fused for half of their length.....2
   Median lobes separated for more than half of their length.....3

2. Median lobes almost triangular, with fine serrations on lateral margins; one to three dorsal submedial macroducts on abdominal segments three to five.....nyssae, bark form
   Median lobes rounded at apex, without serrations on lateral margins; more than three dorsal submedial macroducts on abdominal segments four and five.....americana

3. Median lobes more or less elongate, their width less than half of their length; usually completely separated or divergent; on needles or leaf petioles of trees....4

Median lobes usually broad, wider than half of their length; often close together at base, or not strongly divergent.....8

4. Two submarginal macroducts on abdominal segment six; common on leaf of Nyssa.....nyssae, leaf form
No dorsal submarginal macroducts on abdominal segment six.....5

5. Inner margins of median lobes without serrations; distance between median lobes and inner lobule of second pair of lobes as wide or wider than width of inner lobule; on needles of conifers.....6
Inner margins of median lobes with fine serrations; distance between outer margin of median lobes and inner lobule of second pair of lobes much less than width of inner lobule.....7

6. Mesal margins of median lobes parallel or nearly so; space between mesal margins about one-fourth to one-half of width of one lobe; outer lobule of third pair of lobes bilobed, well-developed and rounded apically.. .....pinifoliae
Mesal margins of median lobes widely divergent, space between mesal margins more than width of one lobe; outer lobule of third pair of lobes strongly reduced, with three to five prominent teeth.....heterophyllae

7. Inner lobule of second pair of lobes protruding beyond apex of median lobe; at least four dorsal submedian macroducts of each of abdominal segments three and four .....platani, leaf form
Inner lobule of second pair of lobes shorter than median lobes, not protruding beyond the apex of median lobe; with zero to one dorsal submedian macroducts on abdominal segment three to six.....triformis, leaf form

8. About one-half or more of ducts in dorsal submedian groups of abdominal segments two to five very small; dorsal submedian group of ducts on abdominal segment six entirely or mostly of small ducts, seldom mixed with macroducts.....salicisnigrae
Not as above.....9

9. No dorsal submedian macroducts on abdominal segment three; if present, lacking dorsal submedian macroducts on abdominal segment six.....10
More than one dorsal submedian macroduct on each side of abdominal segments three and six.....12

10. Median lobes distinctly broad, wider than long, semicircular, close to each other; basal zygosis elongate, protruding anteriorly; a distinct sclerotized horizontal bar at base of each median lobe; on Rosaceae.....furfura
    Median lobes not as above.....11

11. Dorsal submedian and submarginal macroducts totaling less than six from abdominal segments three to six..... .....triformis, bark form
    Dorsal submedian and submarginal macroducts totaling at least seven or more from abdominal segments three to six.....nr. kosztarabi

12. Mesal and lateral margins of median lobes with irregular notches; no dorsal submedian macroducts on abdominal segment two.....platani, bark form
    Mesal and lateral margins of median lobes with fine serrations, straight, with pointed apex; several dorsal macroducts on both submedian and submarginal areas of abdominal segment two.....lintneri

Chionaspis americana Johnson, 1896

Common (or Suggested) Name: elm scurfy scale.
Morphological Similarities: This species had median lobes that were closely appressed, notched on the lateral margins, and yoked by an elongate slcerosis.
Field Description: Scale of the female was 1.5-3.0 mm long, oystershell shaped, white to gray, with a brown terminal exuviae.
Habit: Adult females were found on the twigs.
Distribution: (Appendix C-39).
    County: Blount; Sevier.
    Locale: Greenbriar; Tremont; Trilium Gap Trail; Tuckaleechee Village.
    Elevation: 335-488 m, 915 m.
Host(s): Carpinus caroliniana Walter (American hornbeam); Fagus grandifolia Ehrhart (American beech); Ulmus rubra Muhlenberg (slippery elm).
Biology: Live females were collected in June in the GSMNP. Johnson (1896) and Willoughby and Kosztarab (1974) reported this species was bivoltine in Illinois and Virginia, respectively. Willoughby and Kosztarab (1974) also stated that eggs and a few gravid females overwintered.
Economic Importance: This species was not economically important in the GSMNP, but Baker (1972) stated that heavy infestations may kill twigs, branches, and small trees and seriously injure large trees.

Remarks: This species was collected concurrently with Chionaspis nr. kosztarabi Takagi and Kawai and C. triformis Tippins and Beshear. Although C. americana was not known to have a leaf form, it could be part of a larger complex of polymorphic species. Further biosystematic research is needed to determine these relationships.

Chionaspis furfura (Fitch), 1857

Common (or Suggested) Name: scurfy scale.
Morphological Similarities: C. furfura was similar to C. salicisnigrae (Walsh). C. furfura could be distinguished by the elongated sclerotic median yoke and the presence of transverse sclerotic bars at the base of each median lobe (Ferris 1937).
Field Description: Scale of the female was 1.5-3.5 mm long, oystershell shaped, white, with a brown terminal exuviae. Male scale covers were white, tricarinate, with a yellow terminal exuviae.
Habit: Females and males were found on the twigs and smaller branches near bark crack and crevices.
Distribution: (Appendix C-40).
County: Blount; Cocke; Sevier.
Locale: Appalachian Trail at Newfound Gap; Cosby Campground; Spence Field.
Elevation: 701 m, 1493 m, 1646 m.
Host(s): Malus angustifolia (Aiton) Michaux (southern crab apple); Sorbus americana Marshall (American mountain-ash).
Biology: This species was reported to overwinter as eggs which hatched in late April (Kosztarab 1963). Kosztarab also reported two generations per year based on the presence of eggs in July. Adult females were collected from mid-August until late August in the GSMNP.
Economic Importance: The scurfy scale was not considered to be of economic importance in the GSMNP. Kosztarab (1963) stated this species was a pest in chemically untreated orchards in Ohio.
Remarks: The scurfy scale was collected from hosts of the Rosaceae only.

Chionaspis heterophyllae Cooley, 1897

Common (or Suggested) Name: pine scale*.
Morphological Similarities: The pine scale was a "phenacaspis" form Chionaspis found on conifer leaves (Nakahara 1975). This species was similar to C.

pinifoliae (Fitch), the other "phenacaspis" form Chionaspis which also occurred on conifer leaves. C. heterophyllae can be distinguished from C. pinifoliae by the narrow, strongly divergent median lobes.

Field Description: Scale of the female was 2.0-4.0 mm long (Dekle 1976, Kosztarab 1963), and varied in width depending on the width of the host needle (Ferris 1937). The scale was white with a yellow to golden brown terminal exuviae.

Habit: Adult females were collected from the needles.

Distribution: (Appendix C-41).

County: Blount; Cocke; Sevier.

Locale: Boogertown; Foothills Parkway; Greenbriar; Little River Gorge; Tuckaleechee Village.

Elevation: 335-610 m.

Host(s): Pinus virginiana Miller (Virginia pine).

Biology: Kosztarab (1963) reported this species overwintered in the egg stage and was bivoltine. Adult females were collected in the GSMNP in early July and August.

Economic Importance: Economically important infestations of this species were not observed in the GSMNP.

Remarks: This species was considered to be uncommon in the GSMNP.

Chionaspis nr. kosztarabi Takagi and Kawai, 1967

Common (or Suggested) Name: Kosztarab scale*.

Morphological Similarities: Nakahara (1978) examined specimens from the GSMNP and stated this species closely resembled C. kosztarabi. The median lobes of this species resembled those of C. triformis Tippins and Beshear, but had fewer dorsal ducts. Some specimens also resembled the leaf form of C. gleditsiae Sanders, but the pygidial lobes were different. These specimens were collected along with C. americana on the bark of the same host, American hornbeam. Although the leaf form of C. americana was not known, Nakahara (1978) believed C. nr. kosztarabi was a host-induced variant of another Chionaspis sp. or a new species.

Field Description: Scale of the female was 1.5-3.0 mm long, oystershell shaped, white to dirty white, with a pale yellow terminal exuviae.

Habit: Adult females were found on the leaf margin.

Distribution: (Appendix C-42).

County: Blount; Cocke; Sevier.

Locale: Bote Mountain trailhead; Cosby Campground; Emerts Cove; Greenbriar; Tremont; Y.

Elevation: 366-579 m.

Host(s): Carpinus caroliniana Walter (American hornbeam).

Biology: Willoughby and Kosztarab (1974) reported this

bivoltine species overwintered as mature fertilized females that laid eggs in early spring which hatched in May. They also reported the occurrence of leaf infesting-females.

Economic Importance: This species was not economically important in the GSMNP but Willoughby and Kosztarab (1974) stated that heavy infestations on ornamental Fraxinus spp. could cause death of the tree.

Remarks: This species was believed to be involved in a complex of species that exhibited host-induced morphological variation (Nakahara 1978). The females of two additional species, the elm scurfy scale and C. triformis Tippins and Beshear, were collected from the same host plant and were present on slide mounts processed from the same collection. Further biosystematic research is needed to explain this variation.

Chionaspis lintneri Comstock, 1883

Common (or Suggested) Name: Lintner scale*.

Morphological Similarities: C. lintneri was similar to C. platani (Cooley) but the inner lobule of the second lobe of C. lintneri was without a notch on the lateral margin and the inner lobule of the second lobe of C. platani had a lateral notch.

Field Description: Scale of the female was 2.0-2.5 mm long, oystershell shaped, dirty white to tan, with a yellow to brown terminal exuviae.

Habit: Adult females were found on the twigs and main stem.

Distribution: (Appendix C-43).
County: Sevier.
Locale: Chinquapin Ridge.
Elevation: 1067 m.

Host(s): Pyrularia pubera Michaux (oilnut).

Biology: No information was available on the life history of this species. Adult females were collected from the GSMNP in early August.

Economic Importance: This species was not economically important in the GSMNP.

Remarks: This species was collected from a parasitic plant, oilnut, a new host record.

Chionaspis nyssae Comstock, 1881

Common (or Suggested) Name: sourgum scale*.

Morphological Similarities: The sourgum scale was separated from other Chionaspis spp. by the presence of two submarginal macroducts anterior to the base of the

second lobes. Chionaspis sylvatica Sanders became a junior synonym of C. nyssae when Takagi and Kawai (1967) evaluated this genus and Phenacaspis. Later, Knipscher et al. (1976) verified this dimorphism with biosystematic evidence.

Field Description: The scale of the female was 0.8-1.1 mm long, 0.4-0.5 mm wide, oystershell shaped, white to gray, with a yellow terminal exuviae. The scale covers were similar on the leaves except they were broadened posteriorly into a wedge-like shape. The scale of the male was smaller, white, and faintly to distinctly tricarinate.

Habit: Females and males were found on both the twigs and leaves. Males occurred on upper and lower leaf surfaces and leaf petioles. Females were present on leaf margins on the upper leaf surface and near leaf veins.

Distribution: (Appendix C-44).

County: Blount; Cocke; Sevier.

Locale: Abrams Falls Trail; Cherokee Orchard Loop; Cold Spring Gap; Cosby Creek; Flat Ridge; Foothills Parkway; Gabes Mountain Trail; Greenbriar; Huskey Gap; Laurel Falls; Little River Gorge; Low Gap; Maddron Bald Trail; Meigs Mountain Trail; Pine Oak Trail; Rabbit Creek; Ramsey Cascades; Sams Gap; Sugarlands; Trilium Gap trailhead.

Elevation: 304-1006 m.

Host(s): Nyssa sylvatica Marshall (blackgum).

Biology: Summer generation crawlers settled near leaf veins and on petioles and developed through maturity at these sites. First instars were found in mid-June and adult females were present in early July in the GSMNP. One female was found with an encapsulated endoparasitoid within her body. Knipscher et al. (1976) reported mated adult females overwintered on the bark and developed through two generations per year in Maryland. Males were common on the leaves and females were common on the bark during the summer generation. Kosztarab (1963) reported eggs were present in May in Ohio.

Economic Importance: This was a very common species in the GSMNP and was found wherever the host occurred. Feeding by the leaf form caused heavy leaf chlorosis which was reported to reduce photosynthesis and ultimately new tissue growth (Zelich 1982).

Remarks: This species was collected more frequently in areas that were previously disturbed. Ferris (1937) stated this species was restricted to Nyssa spp., but Nakahara (1982) listed hosts from genera other than Nyssa.

Chionaspis pinifoliae (Fitch), 1856

Common (or Suggested) Name: pine needle scale.
Morphological Similarities: This species was a "phenacaspis" form Chionaspis similar to C. heterophyllae, but had wider, non-divergent median lobes that were relatively parallel.
Field Description: Scale of the female was 1.4-2.3 mm long, 0.9-1.2 mm wide, white, elongated, with an opaque terminal exuviae. The scale of the male was 1.1-1.4 mm long, 0.4 mm wide, white, noncarinate, with a golden terminal exuviae.
Habit: Adult females and immatures were found on the needles.
Distribution: (Appendix C-45).
County: Blount; Sevier; Swain, North Carolina.
Locale: Abrams Falls parking area and Trail; Andrews Bald; Boogertown; Bote Mountain Trailhead; Cades Cove; Chimney Tops; Craig Cove; Glades; Junglebrook; Laurel Falls; Little Greenbriar School; Pine Oak Trail; Polecat Ridge; Rabbit Creek; Sugarlands; Tremont; Tuckaleechee Village; Wears Road.
Elevation: 335-793 m, 1310 m, 1768 m.
Host(s): Pinus strobus L. (eastern white pine); Pinus virginiana Miller (Virginia pine); Tsuga canadensis (L.) Carriere (eastern hemlock).
Biology: Information on the number of generations per year varied, but all investigators agreed that eggs overwintered (Kosztarab 1963, Ruggles 1931, Stimmann 1969). Peak emergences of males were reported to occur three times a year in Ohio and crawlers initially appeared from late April until mid-May (Kosztarab 1963).
Economic Importance: This scale was not considered to be economically important in the GSMNP, but was reported to be a serious threat to pine plantations (Beal 1952). Baker (1972) stated that heavy infestations caused needle chlorosis and could cause mortality among small trees. The chlorosis and reduction of photosynthesis caused by this species has been quantified by Walstad et al. (1973).
Remarks: The collection frequency of this species ranked third among the species of the GSMNP and was considered to be very common.

Chionaspis nr. platani Cooley, 1899

Suggested (or Common Name): witherod scale*.
Morphological Similarities: C. platani was similar to C. lintneri, but the inner lobule of the second lobe was

notched on the lateral margin. Specimens from the GSMNP also had fewer submedial dorsal macroducts on abdominal segments three to six.

Field Description: Scale of the female was 1.4-2.1 mm long, 0.7-1.2 mm wide, oystershell shaped, tan to dirty white, with a brown terminal exuviae. Scale of the male was 0.8-1.0 mm long, 0.2-0.3 mm wide, white, tricarinate, with a golden brown terminal exuviae.

Habit: Adult females and males were found on the twigs, especially near the terminal buds.

Distribution: (Appendix C-46).
County: Blount.
Locale: Thunderhead Mountain.
Elevation: 1686 m.

Host(s): Viburnum cassinoides L. (witherod).

Biology: Little life history information was available for this species except that bark and leaf forms were known. Eggs were found beneath the scales in mid-August in the GSMNP.

Economic Importance: This species was not economically important in the GSMNP.

Remarks: This species was difficult to identify. Morphological characters were intermediate between the bark form of C. platani and C. gleditsiae Sanders, but was closest to C. platani. This species was previously recorded from Platanus only. This collection represented either a new host record, an intermediate form of another Chionaspis sp., or a new species.

Chionaspis salicisnigrae (Walsh), 1868

Common (or Suggested) Name: black willow scale*.

Morphological Similarities: The black willow scale could be recognized by the submedial group of small ducts on the sixth abdominal segment.

Field Description: The scale of the female was 2.0-4.0 mm long, oystershell shaped, white, with a yellow to golden terminal exuviae. Male scale covers were elongate and tricarinate, with a yellow terminal exuviae.

Habit: Females were found on the twigs. Males occurred on both twigs and leaves.

Distribution: (Appendix C-47).
County: Blount; Cocke.
Locale: Cosby Campground; Rabbit Creek.
Elevation: 396 m, 701 m.

Host(s): Liquidambar styraciflua L. (sweetgum).

Biology: Adult females were found in late August through September in the GSMNP, and purple eggs overwintered. Kosztarab (1963) and Langford (1926) reported two generations per year. Kosztarab (1963) reported eggs

hatched in early May.
Economic Importance: This species was not economically important in the GSMNP, but Pirone (1970) stated heavy infestations could kill branches and small trees of Salix spp.
Remarks: The collection from L. sytraciflua represented the first records from this host in the United States.

Chionaspis triformis Tippins and Beshear, 1970

Common (or Suggested) Name: birch chionaspis*.
Morphological Similarities: This species was similar to C. nr. kosztarabi, but was distinguised from this species by the fewer dorsal submedial and submarginal macroducts on the pygidium (Liu et al. 1988).
Field Description: Scale of the female was not measured due to the assumption at collection time that this species was C. nr. kosztarabi. Tippins and Beshear (1970) found the slide-mounted adult females to be 0.9 mm long.
Habit: Females were collected on the leaf margins and twigs.
Distribution: (Appendix C-48).
County: Blount; Sevier.
Locale: Greenbriar; Little River Gorge.
Elevation: 473-488 m.
Host(s): Carpinus caroliniana Walter (American hornbeam).
Biology: Life history information was unavailable for this species. Adult females were collected in July from the GSMNP.
Economic Importance: No economically important infestations were observed in the GSMNP.
Remarks: Although this species conformed to the key characters of C. triformis (Lui et al. 1988), it possessed morphological characters which differentiated it from the concept of C. triformis of Tippins and Beshear (1970). Specimens from the GSMNP on American hornbeam more closely resembled C. nr. kosztarabi (Nakahara 1978). Tippins and Beshear (1970) reported three forms of C. triformis from Georgia and possibly all forms were host-induced morphological variations of one Chionaspis species to which C. nr. kosztarabi is related. Further biosystematic research is required before accurate taxonomic assessment of these species and their variations can be made.

Chionaspis sp. A

Common (or Suggested) Name: silverbell chionaspis.
Morphological Similarities: This species was different from

other Chionaspis spp. of the GSMNP. Proper identification is needed before this species can be evaluated.
Field Description: Scale of the female was not measured due to its poor condition. The length of this species approximated the length of other Chionaspis spp., was oystershell shaped, and brown, with a golden terminal exuviae.
Habit: One adult female was collected from the stem.
Distribution: (Appendix C-49).
County: Sevier.
Locale: Curry Ridge.
Elevation: 676 m.
Host(s): Halesia carolina L. (Carolina silverbell).
Biology: Life history information was available.
Economic Importance: This species was not economically important in the GSMNP.
Remarks: No Chionaspis spp. in the United States has been collected from Carolina silverbell, and this species did not resemble those species known to be polyphagous.

Genus Lepidosaphes Shimer

This genus is represented in North America by 14 species (Nakahara 1982). All of the species were introduced from Europe, except for possibly L. mexicana (Cockerell) (Ferris 1937). L. ulmi (L.) and L. yanagicola Kuwana we collected from the GSMNP. L. ulmi was distinguished from L. yanagicola by the presence of a continuous group of dorsal ducts on the sixth abdominal segment extending from the pygidial margin to near the anus on L. ulmi. These ducts were not present on L. yanagicola (Kosztarab 1963).

Lepidosaphes ulmi (L.), 1758

Common (or Suggested) Name: oystershell scale.
Morphological Similarities: L. ulmi could be recognized by the continuous row of macroducts on the sixth abdominal segment that extended from the pgyidial margin to near the anus.
Field Description: Scale of the female was 1.8-2.6 mm long, 0.4-1.0 mm wide, oystershell shaped, slender, with a golden to yellow exuviae. The color of the scale varied from pale brown to dark brown.
Habit: Females were found on the twigs and branches near cracks and nodes in the bark.
Distribution: (Appendix C-50).
County: Blount; Cocke; Swain, North Carolina.
Locale: Mount Cammerer; Mount Sterling; Sheep Pen Gap.
Elevation: 1280-1524 m.

Host(s): Acer pensylvanicum L. (striped maple).
Biology: Settled first instars were present in mid-June in the GSMNP, and second instars and young adult females were collected in early July through mid-August. Kosztarab (1963) reported that eggs were laid in late August through early September, overwintered, and hatched in mid-May. Males were present from late June to early July. Other workers (Michelbacher and Ortega 1958, Schuh and Mote 1948) reported similar findings and Davidson et al. (1974) stated voltinism varied on different hosts.
Economic Importance: Economically important infestations of this species in the GSMNP were not observed. However, Baker (1972) reported that this species was the primary agent for large scale destruction of ash forests in Ohio. Sanders (1904) reported damage and mortality of poplars and willows in Ohio also.
Remarks: This cosmopolitan species was recorded from many hosts in the eastern United States (Baker 1972), but had a very limited host distribution in the GSMNP.

Lepidosaphes yanagicola Kuwana, 1925

Common (or Suggested) Name: yanagicola scale*.
Morphological Similarities: L. yanagicola was distinguished by having four to nine submedial macroducts on segments two to four of the dorsal pygidium and only two or three such ducts on segment six.
Field Description: Scale of the female was 1.8-2.0 mm long, oystershell shaped, dark brown, with a terminal orange yellow exuviae (Kosztarab 1963).
Habit: Adult females were collected on the twigs and small branches.
Distribution: (Appendix C-51).
County: Blount; Sevier.
Locale: Boogertown; Polecat Ridge.
Elevation: 396 m, 671 m.
Host(s): Acer negundo L. (boxelder); A. pensylvanicum L. (striped maple).
Biology: Porter et al. (1959) stated females overwintered and produced eggs in early June into July, which hatched beginning mid-June. Adult females were collected in late May in the GSMNP environs.
Economic Importance: No economic damage was observed in the GSMNP. Kosztarab (1963) reported that heavy infestations and economic damage occurred in some Ohio nurseries.
Remarks: Collection of this species on Acer spp. was a new host record.

Genus Unaspis MacGillivray

The genus Unaspis in North America contains two species, both introduced into the United States. U. euonymi (Comstock) was collected in the GSMNP.

Unaspis euonymi (Comstock), 1881

Common (or Suggested) Name: euonymus scale.
Morphological Similarities: This species was recognized by the dorsal median pygidial furrow present from the anal opening to the median lobes.
Field Description: Scale of the female was 1.4-1.6 mm long, 0.5-0.7 mm wide, oystershell shaped, dark brown, with a yellow terminal exuviae. Scale of the male was 1.1-1.3 mm long, 0.2-0.3 mm wide, white, tricarinate, with a yellow terminal exuviae.
Habit: Adult females and males were taken from the stems and leaves.
Distribution: (Appendix C-52).
County: Blount; Cocke; Sevier; Swain, North Carolina.
Locale: Boogertown; Cosby Campground; Emerts Cove; Indian Camp Creek; Junglebrook; Meigs Mountain Trail; Noland Creek; Ramsey Cascades; Tuckaleechee Village.
Elevation: 335-396 m, 610-793 m.
Host(s): Euonymus americanus L. (strawberry-bush).
Biology: Gill et al. (1982) reported that voltinism for this species varied from different regions, but found two generations per year in Maryland and mated adult females overwintered. Kosztarab (1963) reported similar findings in Ohio.
Economic Importance: This species was considered to be a major pest of cultivated ornamental Euonymus spp. and bittersweet, Celastrus scandens L., in the United States (Dekle 1976, Pirone 1970). High populations were observed in the GSMNP, especially in the Noland Creek section, which could lead to loss of individual host plants.
Remarks: This species was considered to be common in the GSMNP.

Genus Velataspis Ferris

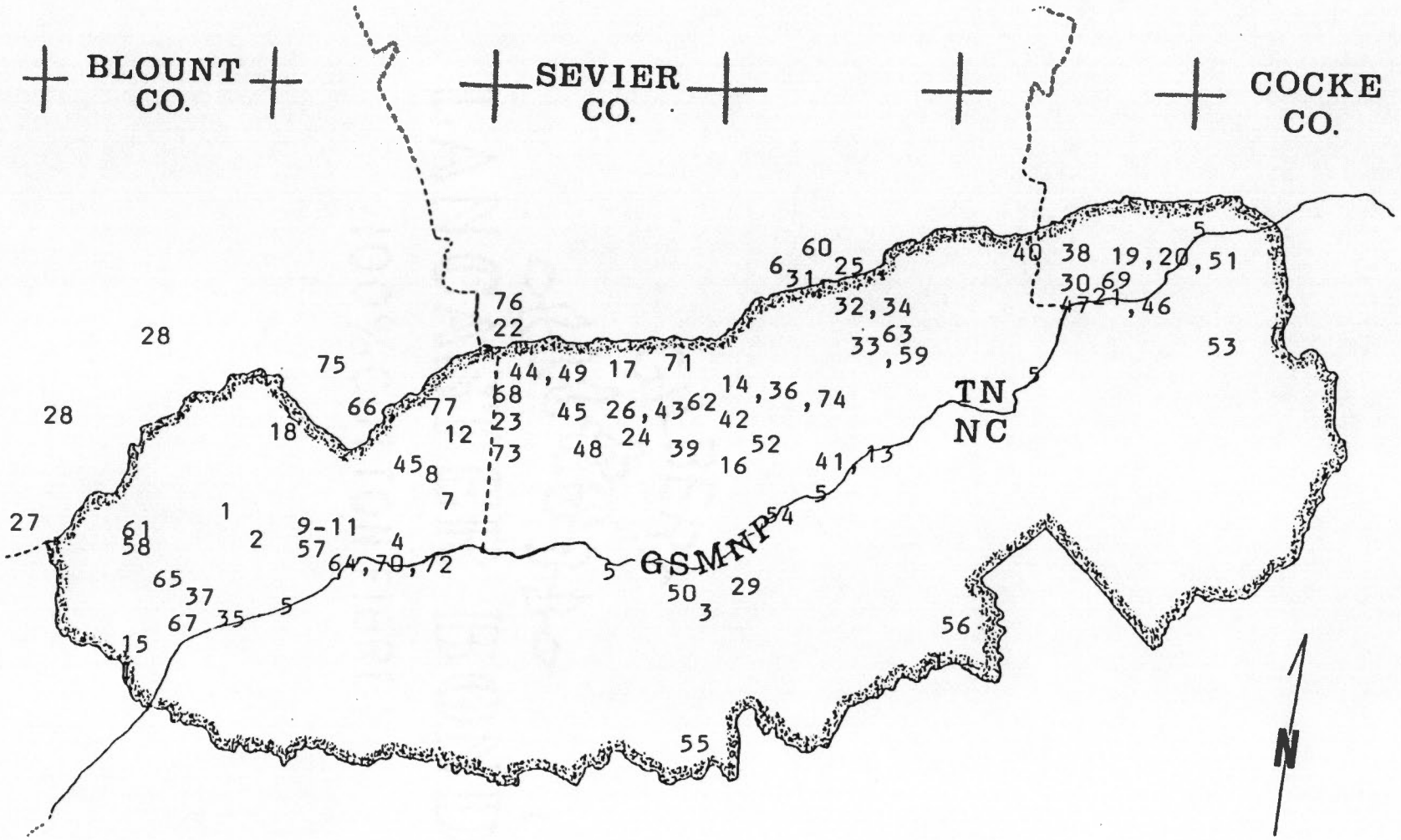
This is a small genus that contains three North American species. V. dentata (Hoke) was collected from the GSMNP.

Velataspis dentata (Hoke), 1921

Common (or Suggested) Name: dentata scale*.
Morphological Similarities: V. dentata was recognized by the presence of irregular, sclerotic tubercles anterior to the antennal base.
Field Description: Scale of the female was 1.0-1.5 mm long, slender, white, with a terminal exuviae (Ferris 1937).
Habit: Adult females were collected from the leaf of the host.
Distribution: (Appendix C-53).
County: Sevier.
Locale: Boogertown; Wears Road.
Elevation: 396 m, 457 m.
Host(s): Acer negundo L. (boxelder); Cornus florida L. (flowering dogwood).
Biology: No life history information was available for this species.
Economic Importance: This species was not economically important in the GSMNP.
Remarks: This collection represented the most northern distributional record for this species.

APPENDIX B

MAP OF COLLECTION SITES



Sample Area and Collection Sites in the Great Smoky Mountains National Park and Environs (See List of Collection Sites on page 120).

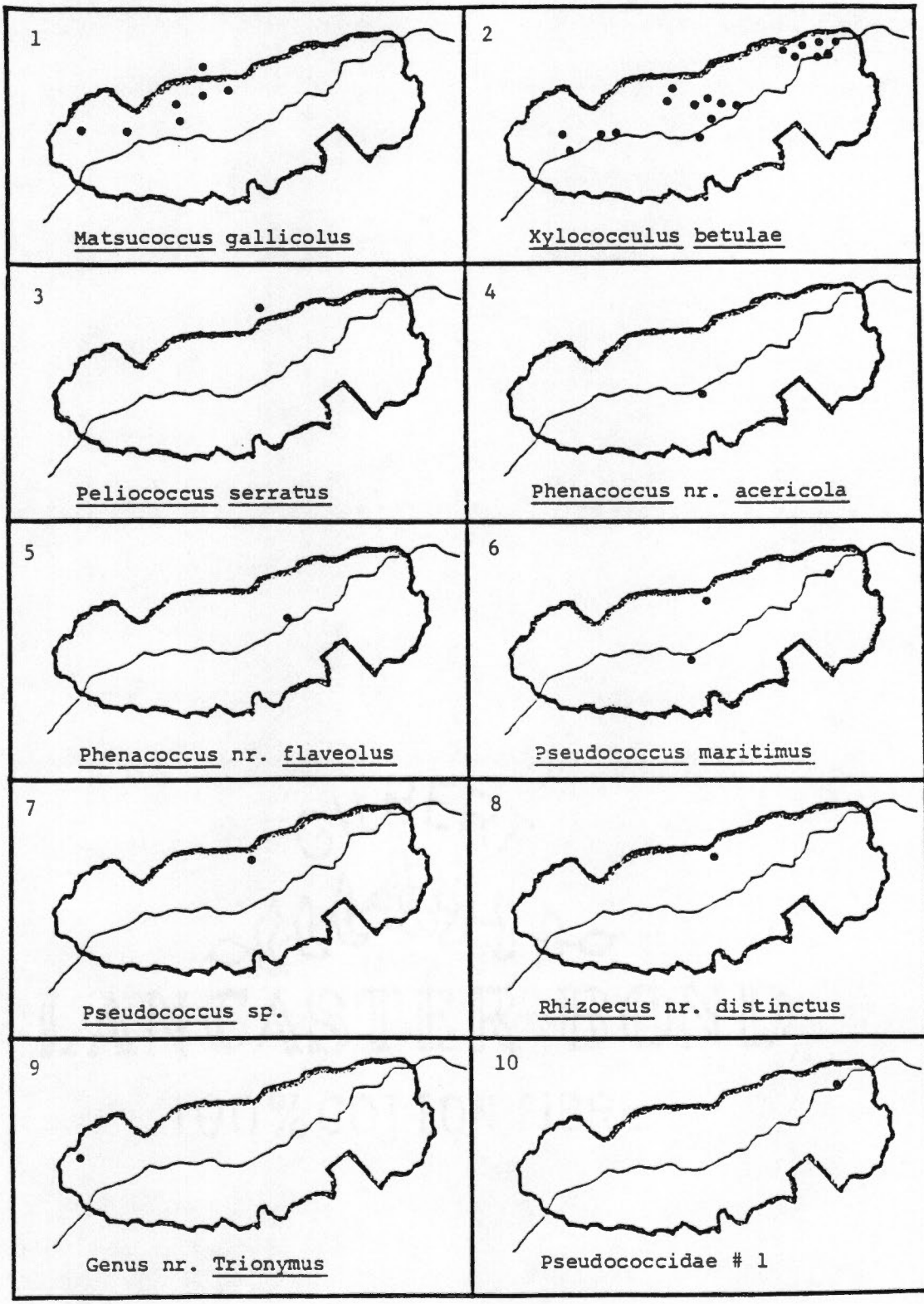
COLLECTION SITES IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK AND ENVIRONS

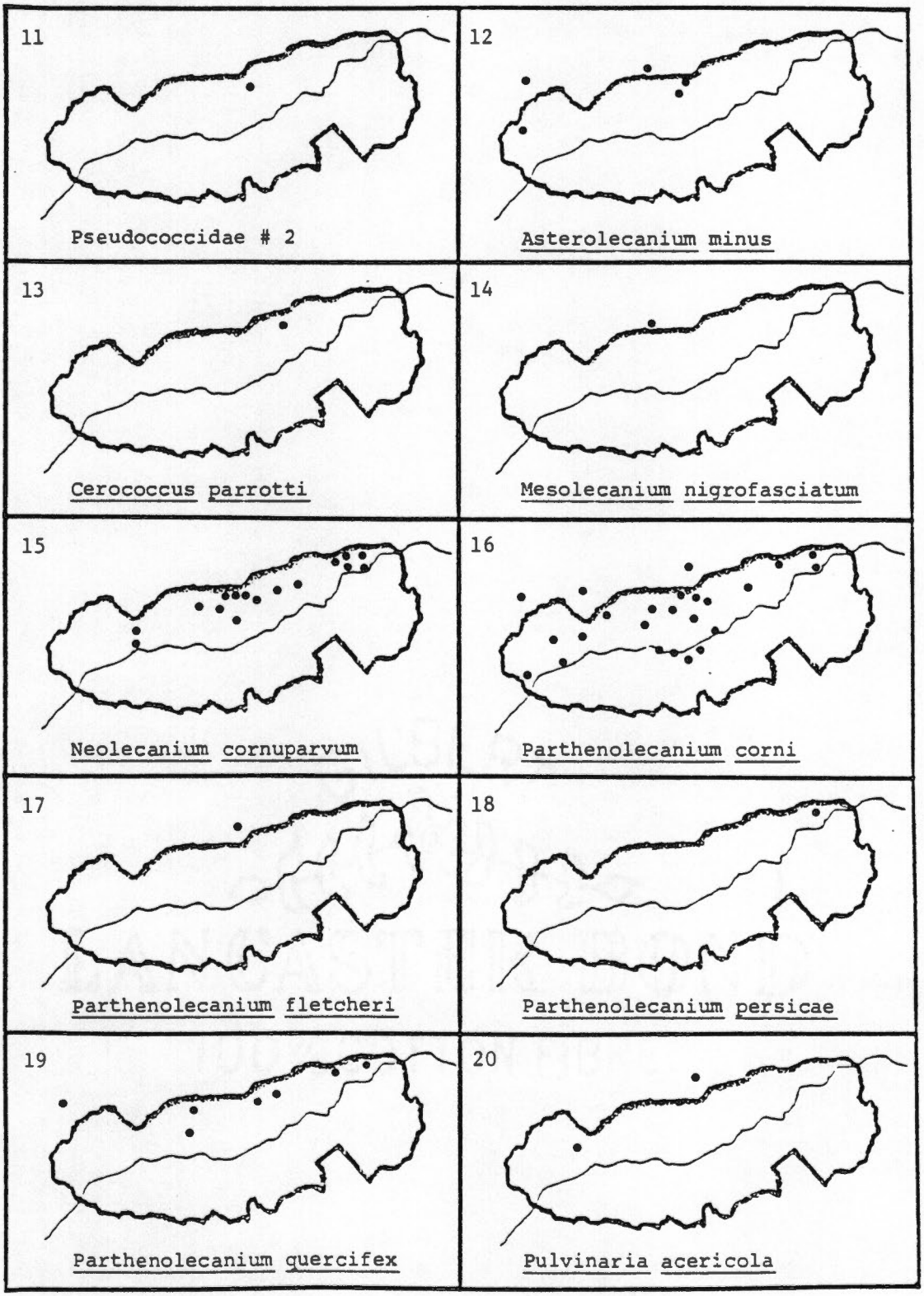
(See Map of Collection Area on page 119)

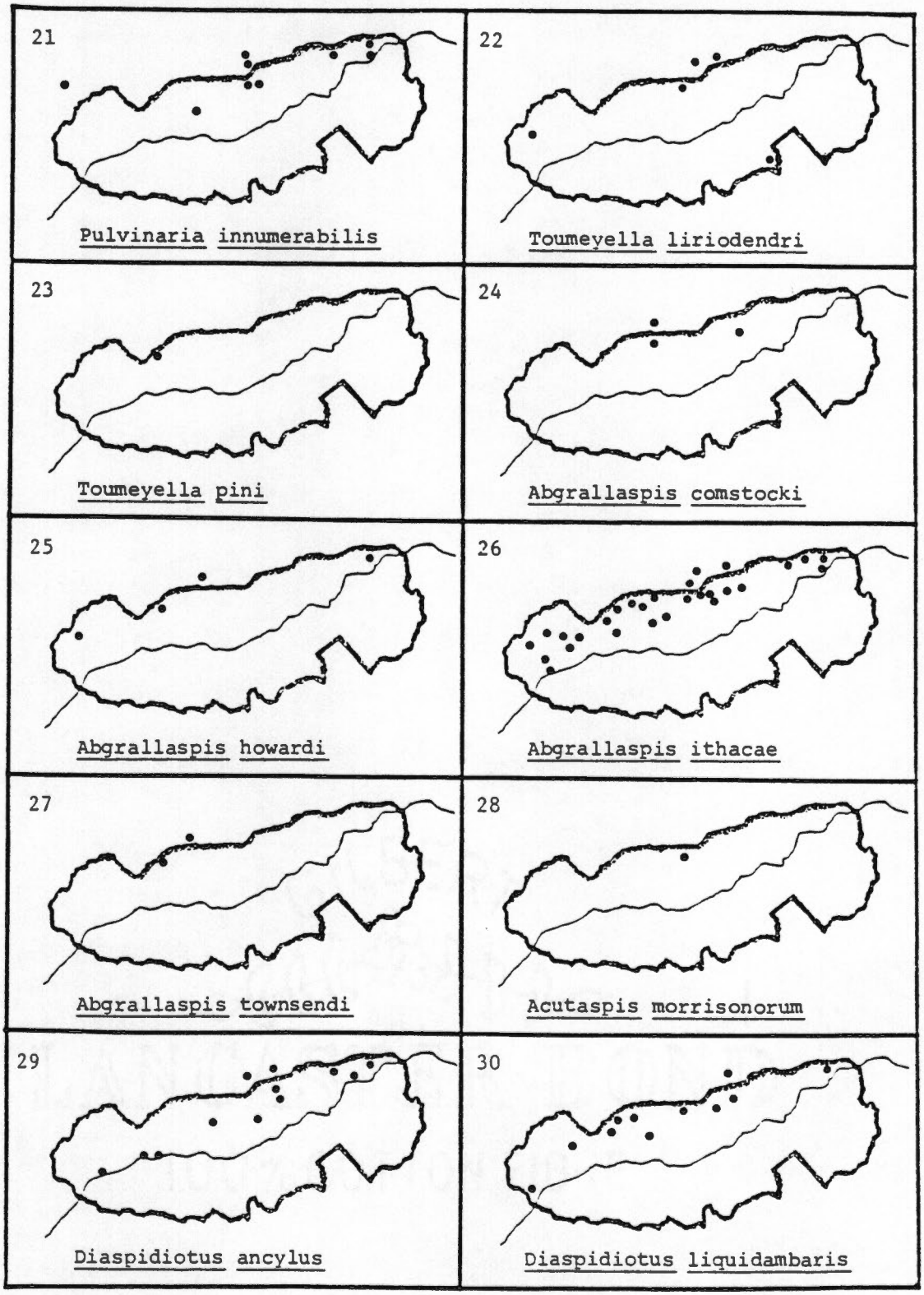
1. Abrams Falls
2. Abrams Falls Parking Area
3. Andrews Bald
4. Anthony Ridge
5. Appalachian Trail
6. Boogertown
7. Bote Mountain
8. Bote Mountain Trailhead
9. Cades Cove
10. Cades Cove Campground
11. Cades Cove General Store
12. Camp Townsend
13. Charlie's Bunion
14. Cherokee Orchard
15. Chilly Spring Knob
16. Chimney Tops
17. Chinquapin Ridge
18. Cold Spring Gap
19. Cosby Campground
20. Cosby Creek
21. Cosby Knob
22. Craig Cove
23. Curry Ridge
24. Elkmont
25. Emerts Cove
26. Fighting Creek Gap
27. Flat Ridge
28. Foothills Parkway
29. Fork Ridge
30. Gabes Mountain
31. Glades
32. Greenbriar
33. Greenbriar Pinnacle
34. Greenbriar Ranger Station
35. Gregory Bald
36. Grotto Falls
37. Hannah Mountain
38. Henwallow Falls
39. Huskey Gap
40. Indian Camp Creek
41. Jumpoff
42. Junglebrook
43. Laurel Falls
44. Little Greenbriar
45. Little River Gorge
46. Low Gap
47. Maddron Bald
48. Meigs Mountain
49. Metcalf Bottoms
50. Mount Buckley
51. Mount Cammerer
52. Mount LeConte
53. Mount Sterling
54. Newfound Gap
55. Noland Creek
56. Oconaluftee Ranger Station
57. Pine Oak Trail
58. Polecat Ridge
59. Porter Flat
60. Proffits General Store
61. Rabbit Creek
62. Rainbow Falls
63. Ramsey Cascades
64. Russell Field
65. Sams Gap
66. Scott Mountain
67. Sheep Pen Gap
68. Sinks
69. Snake Den Trail
70. Spence Field
71. Sugarlands
72. Thunderhead Mountain
73. Tremont
74. Trilium Gap Trailhead
75. Tuckaleechee Village
76. Wears Road
77. Y (Junction of Hwy. 321 and Cades Cove Road)

APPENDIX C

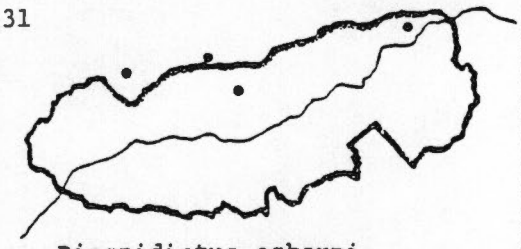
DISTRIBUTION MAPS OF COCCOIDS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK AND ENVIRONS


1
Matsucoccus gallicolus
2
Xylococculus betulae
3
Peliococcus serratus
4
Phenacoccus nr. acericola
5
Phenacoccus nr. flaveolus
6
Pseudococcus maritimus
7
Pseudococcus sp.
8
Rhizoecus nr. distinctus
9
Genus nr. Trionymus
10
Pseudococcidae # 1


11
Pseudococcidae # 2
12
Asterolecanium minus
13
Cerococcus parrotti
14
Mesolecanium nigrofasciatum
15
Neolecanium cornuparvum
16
Parthenolecanium corni
17
Parthenolecanium fletcheri
18
Parthenolecanium persicae
19
Parthenolecanium quercifex
20
Pulvinaria acericola

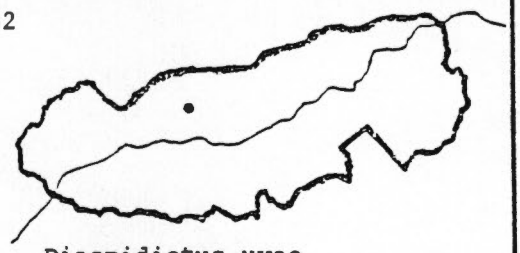

21
Pulvinaria innumerabilis
22
Toumeyella liriodendri
23
Toumeyella pini
24
Abgrallaspis comstocki
25
Abgrallaspis howardi
26
Abgrallaspis ithacae
27
Abgrallaspis townsendi
28
Acutaspis morrisonorum
29
Diaspidiotus ancylus
30
Diaspidiotus liquidambaris

31



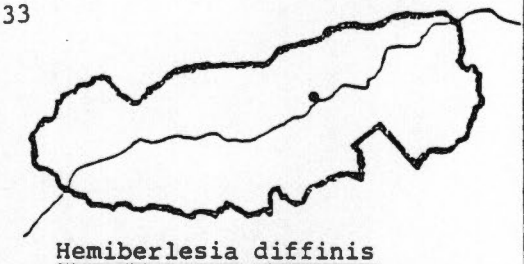
Diaspidiotus osborni

32



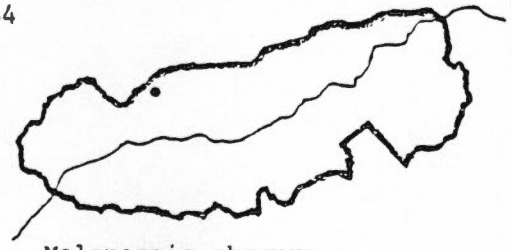
Diaspidiotus uvae

33



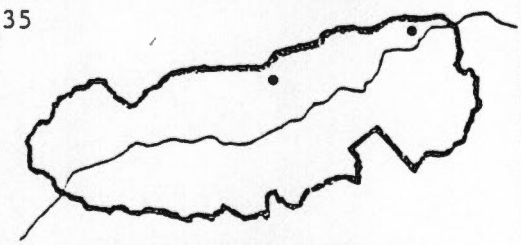
Hemiberlesia diffinis

34



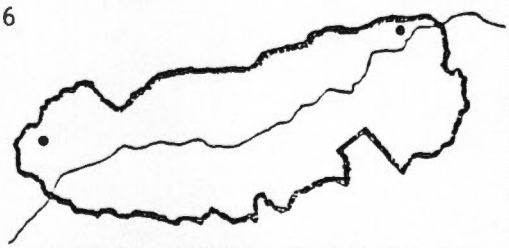
Melanaspis obscura

35



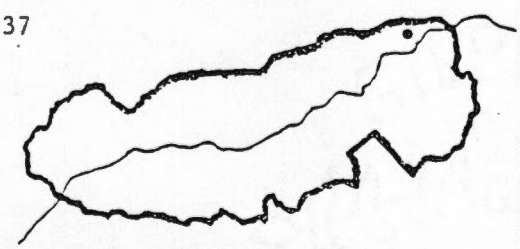
Quadraspidiotus forbesi

36



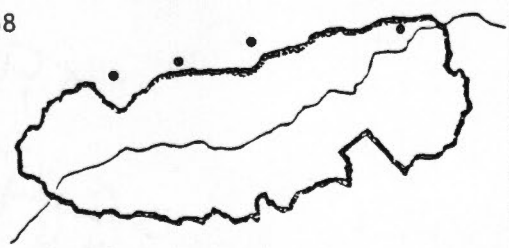
Quadraspidiotus juglansregiae

37



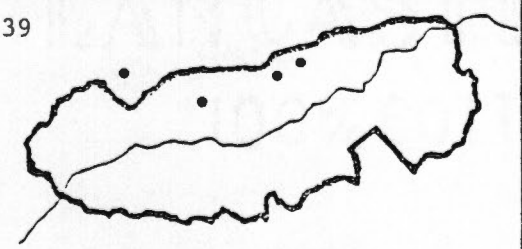
Quadraspidiotus perniciosus

38



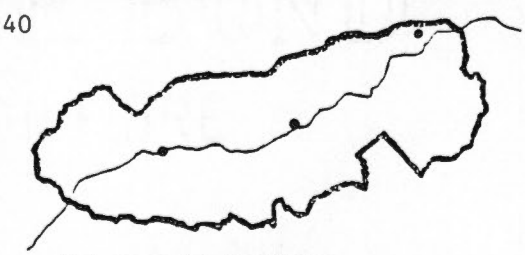
Carulaspis juniperi

39

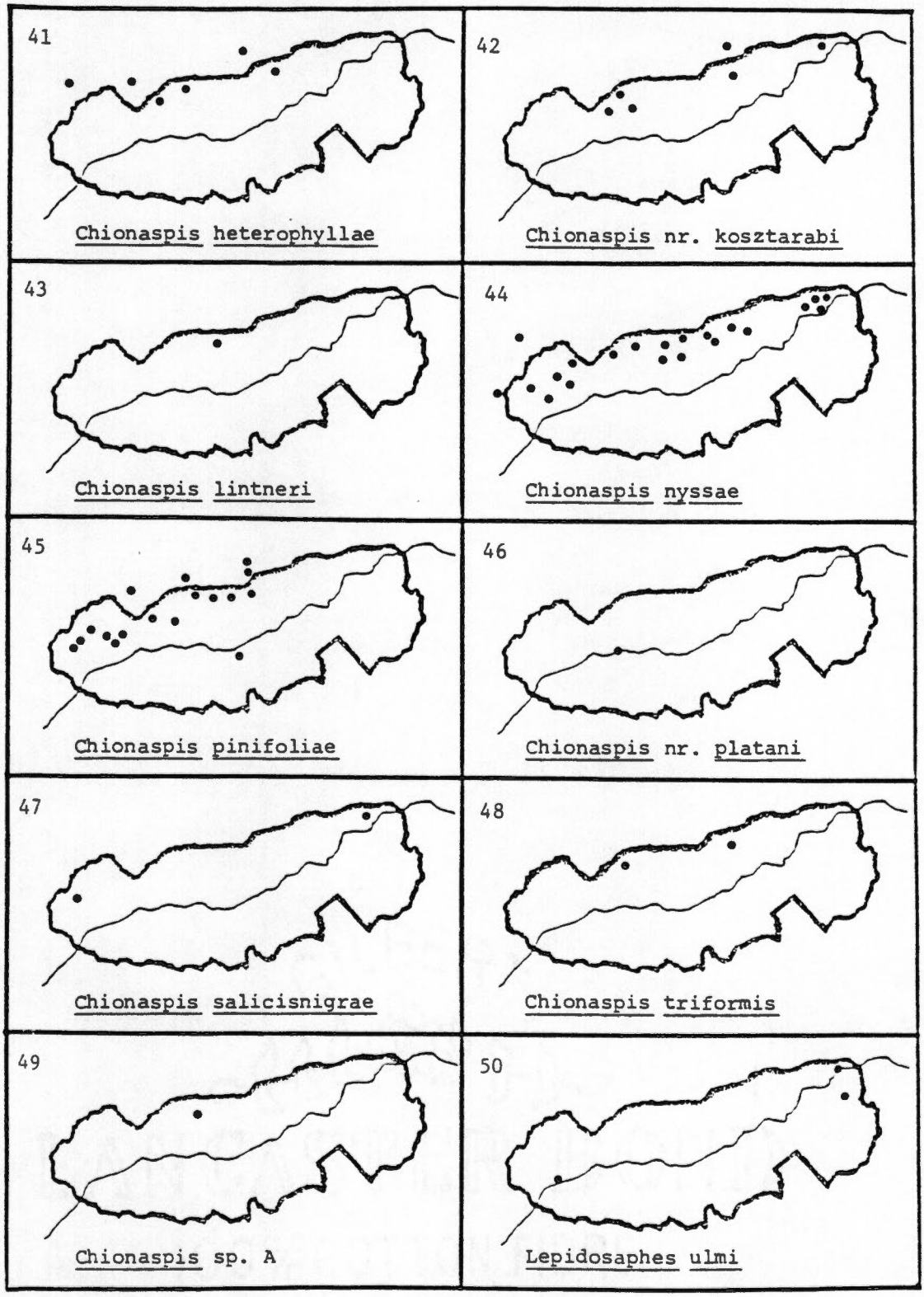


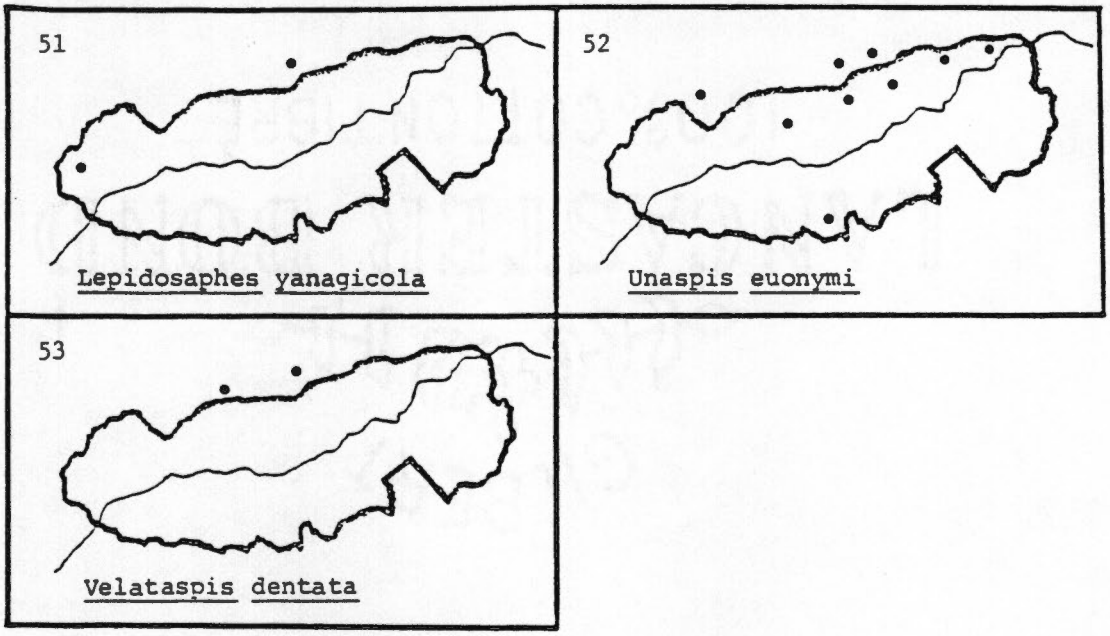
Chionaspis americana

40



Chionaspis furfura


41
Chionaspis heterophyllae
42
Chionaspis nr. kosztarabi
43
Chionaspis lintneri
44
Chionaspis nyssae
45
Chionaspis pinifoliae
46
Chionaspis nr. platani
47
Chionaspis salicisnigrae
48
Chionaspis triformis
49
Chionaspis sp. A
50
Lepidosaphes ulmi


51
Lepidosaphes yanagicola
52
Unaspis euonymi
53
Velataspis dentata

APPENDIX D

HOST INDEX AND ASSOCIATED COCCOIDS

Host Plants of Coccoids of the Great Smoky Mountains National Park and Environs

Host: Family, genus, species, author, approved common name
Coccoid: Genus, species, author, common name

Aceraceae
- Acer negundo L. (boxelder)
  - Diaspidiotus ancylus (Putnam) (Putnam scale)
  - Lepidosaphes yanagicola Kuwana (yanagicola scale)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)
  - Pulvinaria acericola (Walsh and Riley) (cottony maple leaf scale)
  - Pulvinaria innumerabilis (Rathvon) (cottony maple scale)
  - Velataspis dentata (Hoke) (dentata scale)
- Acer pensylvanicum L. (striped maple)
  - Abgrallaspis comstocki (Johnson) (Comstock scale)
  - Lepidosaphes ulmi (L.) (oystershell scale)
  - Lepidosaphes yanagicola Kuwana (yanagicola scale)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)
  - Quadraspidiotus juglansregiae (Comstock) (walnut scale)
- Acer rubrum L. (red maple)
  - Diaspidiotus osborni (Newell and Cockerell) (Osborn scale)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)
  - Pulvinaria acericola (Walsh and Riley) (cottony maple leaf scale)
  - Pulvinaria innumerabilis (Rathvon) (cottony maple scale)
- Acer saccharum Marshall (sugar maple)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)
- Acer spicatum Lamarck (mountain maple)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)

Anacardiaceae
- Rhus copallina L. (shining sumac)
  - Pulvinaria innumerabilis (Rathvon) (cottony maple scale)

Asteraceae
- Aster sp. (aster)
  - Pseudococcidae # 1 (aster mealybug)

Betulaceae
- Betula alleghaniensis Britton (yellow birch)
  - Diaspidiotus ancylus (Putnam) (Putnam scale)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)
  - Pseudococcus maritimus (Ehrhorn) (grape mealybug)
  - Xylococculus betulae (Pergande) (birch margarodid)
- Betula lenta L. (sweet birch)
  - Diaspidiotus ancylus (Putnam) (Putnam scale)
  - Hemiberlesia diffinis (Newstead) (diffinis scale)
  - Phenacoccus nr. flaveolus (Cockerell) (mountain mealybug)
  - Xylococculus betulae (Pergande) (birch margarodid)
- Betula sp. (birch)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)
- Carpinus caroliniana Walter (American hornbeam)
  - Cerococcus parrotti (Hunter) (pecan pit scale)
  - Chionaspis americana Johnson (elm scurfy scale)
  - Chionaspis nr. kosztarabi Takagi and Kawai (Kosztarab scale)
  - Chionaspis triformis Tippins and Beshear (birch chionaspis)
  - Diaspidiotus ancylus (Putnam) (Putnam scale)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)
  - Pulvinaria innumerabilis (Rathvon) (cottony maple scale)

Buxaceae
- Buxus sempervirens L. (common box)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)

Caprifoliaceae
- Viburnum cassinoides L. (witherod)
  - Chionaspis nr. platani Cooley (witherod scale)

Celastraceae
- Euonymus americanus L. (strawberry-bush)
  - Unaspis euonymi (Comstock) (euonymus scale)

Compositae
- Heterotheca graminifolia (Michaux) Shinners
  - genus nr. Trionymus Berg (Rabbit Creek mealybug)

Cornaceae
- Cornus alternifolia L. f. (alternate-leaf dogwood)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)
- Cornus florida L. (flowering dogwood)
  - Abgrallaspis comstocki (Johnson) (Comstock scale)
  - Abgrallaspis howardi (Cockerell) (Howard scale)
  - Abgrallaspis townsendi (Cockerell) (Townsend scale)
  - Cerococcus parrotti (Hunter) (pecan pit scale)
  - Diaspidiotus osborni (Putnam) (Putnam scale)
  - Velataspis dentata (Hoke) (dentata scale)

Cupressaceae
- Juniperus virginiana L. (eastern redcedar)
  - Parthenolecanium fletcheri (Cockerell) (Fletcher scale)
  - Carulaspis juniperi (Bouche) (juniper scale)

Ericaceae
- Vaccinium erythrocarpum Michaux (mountain-cranberry)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)

Fagaceae
- Castanea dentata (Marshall) Borkhausen (American chestnut)
  - Parthenolecanium corni (Bouche) (European fruit lecanium)
  - Diaspidiotus osborni (Putnam) (Putnam scale)
- Fagus grandifolia Ehrhart (American beech)
  - Chionaspis americana Johnson (elm scurfy scale)
  - Peliococcus serratus (Ferris) (serrate mealybug)
- Quercus alba L. (white oak)
  - Asterolecanium minus Lindinger (oak pit scale)
  - Melanaspis obscura (Comstock) (obscure scale)
  - Parthenolecanium quercifex (Fitch) (oak lecanium)
- Quercus prinus L. (chestnut oak)
  - Asterolecanium minus Lindinger (oak pit scale)
  - Parthenolecanium quercifex (Fitch) (oak lecanium)
- Quercus rubra L. (northern red oak)
  - Parthenolecanium quercifex (Fitch) (oak lecanium)
- Quercus stellata Wangenheim (post oak)
  - Parthenolecanium quercifex (Fitch) (oak lecanium)

Hamamelidaceae
- Liquidambar styraciflua L. (sweetgum)
  - Abgrallaspis howardi (Cockerell) (Howard scale)
  - Chionaspis salicisnigrae (Walsh) (black willow scale)
  - Diaspidiotus liquidambaris (Kotinsky) (sweetgum

scale)
Parthenolecanium corni (Bouche) (European fruit lecanium)

Juglandaceae
Carya tomentosa (Poiret) Nuttall (mockernut hickory)
Parthenolecanium corni (Bouche) (European fruit lecanium)

Leguminosae
Robinia pseudoacacia L. (black locust)
Abgrallaspis howardi (Cockerell) (Howard scale)
Diaspidiotus ancylus (Putnam) (Putnam scale)
Quadraspidiotus forbesi (Johnson) (Forbes scale)
Quadraspidiotus juglansregiae (Comstock) (walnut scale)

Magnoliaceae
Liriodendron tulipifera L. (yellow-poplar)
Parthenolecanium corni (Bouche) (European fruit lecanium)
Pulvinaria innumerabilis (Rathvon) (cottony maple scale)
Toumeyella liriodendri (Gmelin) (tuliptree scale)
Magnolia acuminata L. (cucumbertree)
Neolecanium cornuparvum (Thro) (magnolia scale)
Magnolia fraseri Walter (Fraser magnolia)
Neolecanium cornuparvum (Thro) (magnolia scale)

Moraceae
Morus rubra L. (red mulberry)
Parthenolecanium corni (Bouche) (European fruit lecanium)

Nyssaceae
Nyssa sylvatica Marshall (blackgum)
Abgrallaspis comstocki (Johnson) (Comstock scale)
Chionaspis nyssae Comstock (blackgum scale)
Parthenolecanium corni (Bouche) (European fruit lecanium)
Pulvinaria innumerabilis (Rathvon) (cottony maple scale)

Pinaceae
Abies fraseri (Pursh) Poiret (Fraser fir)
Phenacoccus nr. acericola King (maple phenacoccus)
Picea rubens Sargent (red spruce)
Chionaspis pinifoliae (Fitch) (pine needle scale)
Pinus echinata Miller (shortleaf pine)
Matsucoccus gallicolus Morrison (gall pine scale)
Pinus rigida Miller (pitch pine)

Matsucoccus gallicolus Morrison (gall pine scale)
Toumeyella pini (King) (striped pine scale)
Pinus strobus L. (eastern white pine)
Chionaspis pinifoliae (Fitch) (pine needle scale)
Pinus virginiana Miller (Virginia pine)
Chionaspis heterophyllae Cooley (pine scale)
Chionaspis pinifoliae (Fitch) (pine needle scale)
Matsucoccus gallicolus Morrison (gall pine scale)
Tsuga canadensis (L.) Carriere (eastern hemlock)
Abgrallaspis ithacae (Ferris) (hemlock scale)
Acutaspis morrisonorum Kosztarab (round conifer scale)
Chionaspis pinifoliae (Fitch) (pine needle scale)
Pseudococcus sp. (hemlock pseudococcus)
Pseudococcidae # 2 (hemlock bark mealybug)

Platanaceae
Platanus occidentalis L. (sycamore)
Diaspidiotus ancylus (Putnam) (Putnam scale)
Mesolecanium nigrofasciatum (Pergande) (terrapin scale)

Rosaceae
Crataegus sp. (hawthorn)
Parthenolecanium corni (Bouche) (European fruit lecanium)
Malus angustifolia (Aiton) Michaux (southern crab apple)
Chionaspis furfura (Fitch) (scurfy scale)
Malus sylvestris (L.) Miller (apple)
Quadraspidiotus forbesi (Johnson) (Forbes scale)
Quadraspidiotus perniciosus (Comstock) (San Jose scale)
Prunus sp. (cherry)
Parthenolecanium corni (Bouche) (European fruit lecanium)
Pyracantha sp. (firethorn)
Parthenolecanium persicae (Fabricius) (European peach scale)
Rubus canadensis L. (thornless blackberry)
Parthenolecanium corni (Bouche) (European fruit lecanium)
Rubus sp. (blackberry)
Parthenolecanium corni (Bouche) (European fruit lecanium)
Pseudococcus maritimus (Ehrhorn) (grape mealybug)
Sorbus americana Marshall (American mountain-ash)
Chionaspis furfura (Fitch) (scurfy scale)

Salicaceae
Salix nigra Marshall (black willow)

Parthenolecanium corni (Bouche) (European fruit lecanium)

Santalaceae
Pyrularia pubera Michaux (oilnut)
Chionaspis lintneri Comstock (Lintneri scale)

Styracaceae
Halesia carolina L. (Carolina silverbell)
Chionaspis sp.
Diaspidiotus ancylus (Putnam) (Putnam scale)
Parthenolecanium corni (Bouche) (European fruit lecanium)
Pseudococcus maritimus (Ehrhorn) (grape mealybug)

Tiliaceae
Tilia heterophylla Ventenat (white basswood)
Diaspidiotus ancylus (Putnam) (Putnam scale)
Parthenolecanium corni (Bouche) (European fruit lecanium)
Pulvinaria innumerabilis (Rathvon) (cottony maple scale)

Ulmaceae
Celtis occidentalis L. (hackberry)
Parthenolecanium corni (Bouche) (European fruit lecanium)
Ulmus parvifolia Jacquin (Chinese elm)
Parthenolecanium corni (Bouche) (European friut lecanium)
Ulmus rubra Muhlenberg (slippery elm)
Chionaspis americana Johnson (elm scurfy scale)

Vitaceae
Vitis sp. (grape)
Diaspidiotus uvae (Comstock) (grape scale)

Leaf litter
Rhizoecus distinctus (Hambleton) (root rhizoecus)

APPENDIX E

SPECIES RANKING

SPECIES RANKINGS OF SCALE INSECTS IN THE GSMNP

Species	a	b	c	d	e
Parthenolecanium corni	41	8	9	0.266	1
Abgrallaspis ithacae	32	7	7	0.233	2
Chionaspis pinifoliae	28	7	6	0.215	3
Chionaspis nyssae	21	4	7	0.181	4
Neolecanium cornuparvum	20	5	6	0.176	5
Xylococculus betulae	18	6	8	0.166	6
Diaspidiotus ancylus	14	3	6	0.140	7
Diaspidiotus liquidambaris	11	5	6	0.117	8
Pulvinaria innumerabilis	10	3	5	0.110	9
Unaspis euonymi	9	2	6	0.103	10
Parthenolecanium quercifex	9	3	6	0.103	11
Matsucoccus gallicolus	9	4	3	0.103	12
Chionaspis heterophyllae	7	3	6	0.084	13
Chionaspis nr. kosztarabi	7	3	4	0.084	14
Toumeyella liriodendri	5	3	4	0.066	15
Asterolecanium minus	5	3	2	0.066	16
Chionaspis americana	4	3	4	0.057	17
Diaspidiotus osborni	4	3	3	0.057	18
Abgrallaspis howardi	4	2	4	0.057	19
Chionaspis furfura	3	3	3	0.042	20
Pseudococcus maritimus	3	3	3	0.042	21
Carulaspis juniperi	5	1	4	0.066	22
Abgrallaspis comstocki	3	2	2	0.042	23
Lepidosaphes ulmi	3	1	2	0.042	24
Quadraspidiotus juglansregiae	2	2	2	0.030	25
Chionaspis salicisnigrae	2	2	2	0.030	26
Chionaspis triformis	2	2	2	0.030	27
Lepidosaphes yanagicola	2	2	2	0.030	28
Pulvinaria acericola	2	1	2	0.030	29
Quadraspidiotus forbesi	2	1	2	0.030	30
Velataspis dentata	2	1	2	0.030	31
Cerococcus parrotti	2	1	1	0.030	32
Abgrallaspis townsendi	2	1	1	0.030	33
Quadraspidiotus perniciosus	1	1	1	0.017	34
Melanaspis obscura	1	1	1	0.017	35
Mesolecanium nigrofasciatum	1	1	1	0.017	36
Parthenolecanium fletcheri	1	1	1	0.017	37
Aster mealybug	1	1	1	0.017	38
Toumeyella pini	1	1	1	0.017	39
Parthenolecanium persicae	1	1	1	0.017	40
Hemiberlesia diffinis	1	1	1	0.017	41
Diaspidiotus uvae	1	1	1	0.017	42
Acutaspis morrisonorum	1	1	1	0.017	43
Peliococcus serratus	1	1	1	0.017	44
Chionaspis lintneri	1	1	1	0.017	45
Chionaspis nr. platani	1	1	1	0.017	46

Species	a	b	c	d	e
Chionaspis sp. A	1	1	1	0.017	47
Phenacoccus nr. acericola	1	1	1	0.017	48
Phenacoccus nr. flaveolus	1	1	1	0.017	49
Pseudococcidae #2	1	1	1	0.017	50
Rhizoecus distinctus	1	1	1	0.017	51
Genus nr. Trionymus	1	1	1	0.017	52
Pseudococcus sp.	1	1	1	0.017	53

a = Number of times the species was collected in 68 collecting trips.
b = Number of vegetative cover types species was collected from.
c = Number of sample blocks species was collected from.
d = Shannon-Weaver Diversity Index value.
e = Cumulative Importance of species collected.

VITA

John Keith Watson is the son of Mr. John Bartlett Watson and Mrs. Sara Frances Mize Watson of Sevierville, Tennessee. Keith was born in El Paso, Texas on the 19th day of October, 1954 at Biggs Air Force Base. He attended several primary schools throughout the eastern United States as a dependent in the United State Air Force. Keith attended and graduated from Rudyard High School, Rudyard, Michigan in June of 1972. Keith continued to pursue his educational career at the University of Tennessee where he was enrolled in the Forestry curriculum. He was graduated cum laude in June 1976 with his Bachelor of Science degree in Forestry. Keith began graduate studies in Entomology at the University of Tennessee in June 1976 where he began this study. After a delay from graduate studies, Keith returned to the University of Tennessee to complete his studies, from which he will graduate in August 1988. Keith has accepted employment with the University of Tennessee as a Research Assistant now studying the Lepidoptera of the Great Smoky Mountains National Park.

Keith has three wonderful children, Erik Christopher, Shane Nicholas, and Dawn Nicole, who live in Knoxville, Tennessee.

Keith is married to Ms. Ruth A. Barber of Knoxville, Tennessee.