A COMMUNITY ECOLOGY STUDY OF A DISJUNCT POPULATION OF TOMANTHERA AURICULATA (MICHAUX) RAFINESQUE (SCROPHULARIACEAE) IN MONTGOMERY COUNTY, TENNESSEE

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A Community Ecology Study of a Disjunct Population of *Tomanthera auriculata* (Michaux) Rafinesque (Scrophulariaceae) in Montgomery County, Tennessee

A Thesis

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DEDICATION

This thesis is dedicated to my husband

Frank E. Goodlett

and

my family

Mom, Dad, and my sister, Shannan

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ABSTRACT

A relatively large population (>3,900 stems in 1994) of *Tomanthera auriculata* (Michaux) Rafinesque (Scrophulariaceae), an annual hemiparasite, occurs on barrens of the Fort Campbell Military Reservation, Montgomery County, Tennessee. The once wide-ranging species (over much of middle North America) has been reduced to scattered populations in about 18 states.

This study examined community ecology of the disjunct Montgomery County, Tennessee, population of *T. auriculata*, which occurs at seven subsites that are similar in topography, elevation, bedrock, and soils. Stem counts in 1994 and 1995 showed a decrease in number of stems from 3900 to 1564 plants. Numbers increased in two subsites burned in winter 1994-1995, decreased in five subsites not burned, and remained stationary in one subsite that was partially burned.

The floras of the seven subsites were closely related (avg. = 57.51%, Sorensen Index). Presence calculations showed a greater than normal percentage of constant species. Two species, *Helianthus occidentalis* and *Schizachyrium scoparium*, had frequencies of 100 percent and may serve as host taxa. Predation did not appear to be a limiting factor for this population. This study indicates that regular habitat disturbance is required for maintenance of this *Tomanthera auriculata* population.

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CHAPTER 1

INTRODUCTION

The eared (or earleaf) false foxglove, *Tomanthera auriculata* (Michaux) Rafinesque (Scrophulariaceae), is a hemiparasitic, annual, vascular species formerly categorized as C2 (under review for threatened or endangered listing) by the U. S. Fish and Wildlife Service (1993). It was first federally listed in 1985 as *Agalinis auriculata* (U. S. Fish and Wildlife Service 1985). However, the C2 classification was revised recently (U. S. Fish and Wildlife Service 1996), and former C2 species are now defined as those for which "further biological research and field study are needed to resolve the conservation status of these taxa."

Tomanthera auriculata once occurred from New Jersey west to Minnesota and south to northern Texas and central Alabama (Pennell 1928) but has been extirpated from most formerly-known sites. Now it is known from only 41 populations in 12 states (Foti 1993, Rawinski 1990). Historical Tennessee records include a literature report from Madison County (Pennell 1928) and a 1959 collection from Carroll County (vouchered by a specimen at The University of Tennessee-Knoxville). Extant Tennessee populations are known from Bledsoe, Tipton, and Roane counties (also vouchered by specimens at The University of Tennessee-Knoxville) and a recently discovered disjunct population in Montgomery County (Chester *et al.* 1996). The species is not known from Kentucky (Browne and Athey 1992).

Description

Tomanthera auriculata is an annual with simple or sparingly branched, four-angled stems up to 8 dm in height (Pennell 1928). Stems are harshly scabrous with mostly retrorse hairs. Leaves are opposite, subsessile or sessile, lanceolate, and up to 2 cm broad and 6 cm long. Leaf

bases are rounded and margins are entire except the margins of the upper leaves which usually bear one to two small and divergent, lanceolate, lateral lobes (auricles). Both stems and leaves are purplish-green in color. Flowers are numerous and sessile in the upper axils, forming a leafy-bracted spike. The calyx is nearly regular, campanulate, 15-20 mm long, and with a densely retrorsely-hairy tube; the lobes are unequal, lanceolate, and slightly longer than the tube. Corollas are zygomorphic, about 2.5 cm long, and pale to dark purplish with the throat darkly-dotted. Flowering is in August and September. Fruits are round-ovoid capsules about 1.5 cm long. Seeds are set in September-October and are numerous in each capsule and reticulate. Mature seeds are dormant when shed in autumn and require cold stratification (12 weeks at about 5° C) to break dormancy, and then light for germination. This corresponds to cold stratification test results in which the optimum thermoperiod for stratification was 15° C day time/6° C night time. Seeds normally germinate in March and April (Baskin *et al.* 1991, Cunningham and Parr 1990).

Tomanthera auriculata is a hemiparasite whose delicate root system forms haustoria usually smaller than 1 mm in diameter within the roots of other vascular plants. Distinctions in host specificity in Scrophulariaceae are described as restricted, narrow, or indiscriminate, and *T. auriculata* best fits the narrow range (Cunningham and Parr 1990). One early study providing insight into *T. auriculata*'s possible hosts comes from a Chicago, Illinois, population discovered by Musselman (1972). Limited excavations revealed haustoria on unknown roots with monocot anatomy thought possibly to be *Poa compressa*. He also germinated cold treated seeds with young *Poa pratense* and *Helianthus annuus*, but the seedlings died prematurely without forming haustoria (Musselman 1972). Replicate experiments by Cunningham and Parr (1990) revealed two successful hosts, *Helianthus occidentalis* and *Rudbeckia fulgida*, out of eight potential hosts.

Plants grown in a greenhouse in the absence of pollinators produced viable seeds, indicating self pollination. Greenhouse plants produced 40-50 seeds per capsule as compared to

field grown plants, which produce 50-180 per capsule. Also, the greenhouse pollen-ovule ratios fall in a range for species thought to typically self-pollinate but with some capacity for outcrossing. The flower buds have well-developed stigmas, and the anthers dehisce before anthesis, but further study of bud formation is needed (Cunningham and Parr 1990). Throughout its evolution, *Tomanthera* has remained a bee pollinated plant though probably not completely dependent on the insect for pollination. It has adapted evolutionarily to bee pollination, however, by changing from its proto-Aureolarioid plain yellow corolla to a purple one with dark purple-red spots located anteriorly within the throat (Pennell 1928).

Taxonomy

The genus name *Tomanthera* was established by Rafinesque in 1837; the name literally means "split anthers," probably in allusion to one pair of anthers being smaller than the other. This small genus with only two species is probably of considerable antiquity and may have been derived, with *Agalinis* and *Virgularia*, from a remote Nearctic proto-Aureolarioid stock (Pennell 1935). *Tomanthera auriculata*, the plant of interest in this study, is considered more primitive than the bipinnatifid-leaved *Tomanthera densiflora*, which is distributed in the midwestern United States. *Tomanthera auriculata* has retained the proto-Aureolarioid features in its erect stem, opposite, ample leaves, foliaceous sepals, glabrous capsules, and unwinged seeds (Pennell 1928). *Tomanthera* is most closely related to the genus *Agalinis*, but differs primarily in flower structure. Flowers of *Tomanthera* are sessile rather than pedicellate as in *Agalinis*, have unequal anther cells (equal in *Agalinis*), and have blunt anther bases (awned in *Agalinis*) (Cunningham and Parr 1990).

Synonyms of *T. auriculata* include *Agalinis auriculata* (Michx.) Blake, *Gerardia auriculata* Michx., *Seymeria auriculata* (Michx.) Spreng., *Tomanthera lanceolata* Raf.,

Otophylla michauxii Benth., *Otophylla auriculata* (Michx.) Small, and *Aureolaria auriculata* (Michx.) Farwell (Foti 1993).

Habitat and Distribution

Based on label data from herbarium specimens and published reports (*e.g.* Knoop 1988), the habitats of *T. auriculata* historically included dry oak woods, gravelly moraines, and dolomitic glades to mesic prairies and marshy borders of prairies ponds. Today, the plant more typically inhabits degraded dry prairies and floodplains, fallow fields, and borders of upland sterile woods and thickets (Watson 1991). Geographically, the species is found mostly in the Prairie Peninsula of the Central Lowlands Province and in the Great Plains Province. Also, there are a few sporadic records from the eastern United States, including some from the Interior Low Plateau, Appalachian Plateaus, Coastal Plain, and from along the Fall Line from New Jersey to Virginia (Orzell and Summers 1983).

Tomanthera auriculata's limited occurrence is exemplified by some recent surveys and status reports. For example, in 1983, the only known extant population in Missouri was in the 14-ha Gravois Creek floodplain in southeastern St. Louis County (Orzell and Summers 1983). The only Oklahoma site (as of 1990) was in Choctaw County where a small population of 10 individuals occurred in a "5-10 square yard" area (Watson 1991). A population of about 50 plants occurred on a degraded moist prairie in the metropolitan Chicago area (Musselman 1972). Several "large" populations of about 200 individuals occurred in 40 ha of a prairie glade in Southern Brushcreek Township, Adams County, Ohio (Knoop 1988).

Listed Status

The formal status designations of *T. auriculata* in the 18 states where it occurs or occurred are: Illinois-imperiled, Indiana-extirpated, Iowa-unknown status, Kansas-critically imperiled,

Maryland-extirpated, Michigan-extirpated, Minnesota-unknown status, Mississippi-proposed endangered, Missouri-watch list, critically imperiled, New Jersey-extirpated, Ohio-endangered, Oklahoma-critically imperiled, Pennsylvania-historical [rediscovered in 1987 (Regan and Smith 1988) and extant in 1989 (Rawinski 1990)], Tennessee-endangered, Texas-historical, Virginia-historical, West Virginia-historical, Wisconsin-historical (Watson 1991).

Objectives

The objective of this study was to investigate ecological relationships of the *T. auriculata* population in Montgomery County, Tennessee, over a two-year cycle (1994 and 1995). The results will help explain why this is a rare species, and provide information that can be used in the development of management and recovery plans.

The following specific questions were addressed:

1. What is unique about the seven subsites in Montgomery County that allows this disjunct population to grow there, and what physical factors, such as soils, bedrock, and elevation, do the subsites have in common?
2. What is the current status of the Montgomery County population of *T. auriculata*, and what are the effects of landscape modification, such as periodic burning and usage by heavy equipment, on population size over the two years of this study.
3. What is the vascular flora of the seven subsites; what species are shared among them; and are the subsites part of the same community based on standard indices of community similarity?
4. What are the associates of *T. auriculata*, *i.e.*, is there a coherent group of species that always grows close enough to provide the required host root system?
5. Are there other factors (pollinators, browsers, *etc.*) that might be observed by careful field observations that are important in the community ecology of this species?

CHAPTER 2

METHODS AND MATERIALS

The Study Sites

The *Tomanthera auriculata* population studied is in Montgomery County, Tennessee, within the Fort Campbell Military Reservation (FCMR), a U. S. Department of Defense installation occupying parts of four counties in Kentucky and Tennessee. The training areas of the Reservation harboring the population are within the Pennyroyal Plain Subsection, Highland Rim Section, Interior Low Plateaus Province of Quarterman and Powell (1978). The Pennyroyal Plain Subsection is a level to rolling upland extending across Kentucky into northern Tennessee and is characterized by upland flats and depressions, sinking streams, upland swamps, and extensive areas referred to as barrens. In fact, the Subsection is nearly coincident with the historic "Big Barrens" of Kentucky and Tennessee (Baskin *et al.* 1994). Barrens are deep-soil, culturally-derived and maintained grasslands dominated by native perennial grasses, but also known to harbor numerous midwestern prairie species. Except for those within the FCMR, most barrens of the Subsection are now used for agricultural production, mostly wheat, soybeans, corn, or pasturing (Baskin *et al.* 1994).

The Montgomery County population of *T. auriculata* consists of seven known subpopulations within a radius of 2 km. The subsites supporting these subpopulations comprise an approximate total area of 98.4 ha (derived from aerial photographs), but the area occupied by *T. auriculata* is much less. Names, locations, and characterizations of the seven subsites are as follows:

Subsite 1: Ghost Corp Trail Site. In the triangle formed by the junction of Ghost Corp Trail and Jordan Springs Road; about 15.8 ha, 174-180 m elevation, level to rolling topography.

Subsite 2: Oriental Village Road Site. A large site just west of the intersection between Hellcat Road and Oriental Village Road, containing a firebreak; about 28.2 ha, 183-189 m elevation, level to rolling topography.

Subsite 3: Oriental Village Road, Northeast Site. Directly north of and separated from subsite 2 by Oriental Village Road; about 5.2 ha, 180-183 m elevation, mostly level topography.

Subsite 4: Oriental Village Road, North-Middle Site. Just west of subsite 3 on the north side of Oriental Village Road; about 14.9 ha, 177-183 m elevation, level to rolling topography.

Subsite 5: Oriental Village Road, Northwestern Site. Just west of subsite 4 and north of a firebreak on south side of Oriental Village Road; about 15.8 ha, 174-177 m elevation, mostly level topography.

Subsite 6: Oriental Village Road, Southern Site. South of subsite 2 and on east side of Oriental Village Road; about 7.5 ha, 183-186 m elevation, mostly level topography.

Subsite 7: Hellcat Barren Site. Easternmost site, south of Hellcat Road; about 13.5 ha, 177-180 m elevation, mostly level topography.

The soils present on the subsites are of the Dickson, Mountview, Arrington, and Crider series (soils information derived from Lampley *et al.* 1975). The Dickson series is a moderately well-drained silt loam soil with a medium available water capacity and a fragipan in most areas. Without liming, the soil is strongly to very strongly acidic. There are two Dickson soil subtypes represented in the study sites. One, DsC, is found in subsites 1 and 2 and is characterized by 4-8 percent slopes on broad uplands. The fragipan is gravelly in a few areas, but it is mostly a light silty clay loam that becomes hard and brittle when dry, causing restriction of root and water movement. The DsC soil is droughty in summer and susceptible to erosion. The second Dickson subtype, DsB, occurs on slopes of 1-4 percent and is found in subsites 1, 2, 3, 5, 6, and 7. The fragipan is mostly gravelly, though completely absent in a few areas, resulting in moderately slow drainage.

The Mountview series is a deep, well-drained silt loam formed in a 2-3 foot layer of loess over old alluvium or cherty residuum derived from limestone. This soil is found mainly on broadly rounded tops of low, rolling hills and consesquently has a deep root zone and high available water capacity. The depth to bedrock is more than 10 feet. This soil also is strongly to very strongly acidic. Two Mountview soil subtypes are represented in the study sites. One, MoB, is found in subsites 3 and 4 and occurs on slopes of 2-5 percent with small areas having a fragipan at about 2 feet. Subtype MoC2 occurs on eroded, 5-12 percent sloping hillsides in subsites 1, 2, 3, and 4.

The Arrington series is a deep, well-drained silt loam soil found in flood plains, bottoms of limestone sinks, and uplands with slopes less than 2 percent. The soil has a high available water capacity with a depth to bedrock of over 8 feet, and though moderately permeable, it is subject to brief flooding in late winter and early spring. This also is a highly fertile soil of neutral to medium acidity with a deep root zone. The Arrington soil is found only in subsite 4.

The final type, Crider, also is found only in subsite 4. This soil is a deep, well-drained silt loam soil which occurs on 2-8 percent sloping uplands with a depth to bedrock more than 10 feet. The upper 2-3 feet were formed in loess and the lower 5 feet or more were formed in residuum or old alluvium. It is a moderately permeable soil of medium to strong acidity with a high available water capacity and a deep root zone.

All sites are underlain by bedrock of the Ste. Genevieve Formation, an Upper Mississippian Limestone characteristic of the Pennyroyal Plain Subsection. This is a cavernous, gray limestone that is often cherty and with some green shale and fine-grained sandstone (Wilson 1986). Few surface exposures occur within the Subsection (Baskin *et al.* 1994).

Field Sampling and Data Analyses

Each of the seven subsites known to support *T. auriculata* was examined throughout 1994 and 1995 to determine if any landscape modifications, such as burning or other disturbances, had occurred. Land-use records on previous usage of the sites were obtained from the FCMR Environmental Office. During September of 1994 and 1995, at the peak of flowering for the species, each field was visited and a count made of all *Tomanthera* plants present. Data were tabulated and variations in counts between the two years determined.

Each field was sampled with m^2 quadrats on 3, 8, 15 September and 6 October 1994, to obtain data on (1) the flora of the sites and (2) associated species. Quadrats were haphazardly placed throughout each *Tomanthera* population, except that each quadrat included at least one healthy *Tomanthera* plant. The number of quadrats per site was based on the relative size of the *Tomanthera* population. Thirty quadrats were taken in subsite 1, 20 in subsite 2, 15 in subsite 3, 25 in subsite 4, 13 in subsite 5, 7 in subsite 6, and 10 in subsite 7, for a total of 120 quadrats. Within each quadrat, all species present were recorded and their coverage values, including bare ground, if any, recorded. Coverage classes, based on the methods of Oosting (1956), are on a scale from 1-5 with coverage class 1 representing less than 5 percent coverage of ground surface; coverage class 2 from 5-25 percent; coverage class 3 from 25-50 percent; coverage class 4 from 50-75 percent; and coverage class 5 from 75-100 percent.

A floristic list was prepared for each of the seven sites and the lists combined to develop a flora for the FCMR *Tomanthera* community; nomenclature follows Wofford and Kral (1993). Sorensen's Index of Community Similarity was calculated for all pairwise combinations to determine if the seven sites represent the same community (Barbour *et al.* 1987). This index is based on the equation $IC_s=(2C/A+B)100$, where A = the number of species in site 1, B = the number of species in site 2, and C = the number of species in common.

Presence, or the percent of sites in which each species occurred, was computed. Presence classes were determined following the schemes of Cain and Castro (1959) and Oosting (1956): presence class (PC) 1 = all species occurring in 1-20 percent of the stands; PC 2 = 21-40 percent; PC 3 = 41-60 percent; PC 4 = 61-80 percent; and PC 5 = 81-100 percent. Presence class distributions were determined and compared with the normal distribution reported by Oosting (1956).

Frequency, or the percent of sample plots in which a species occurred, was computed. Frequency classes were determined as outlined by Oosting (1956): frequency class (FC) A = all species occurring in 1-20 percent of plots; FC B = 21-40 percent; FC C = 41-60 percent; FC D = 61-80 percent; FC E = 81-100 percent. Associates and possible host taxa of *T. auriculata* at the FCMR population were determined from frequency data.

The plant community type supporting *T. auriculata* at FCMR was quantitatively determined by computing an importance value (IV) based on frequency (the percent of quadrats with a species), relative frequency, cover, and relative cover for each species. Summation of the relative values (total possible = 200) allowed for a numerical ranking of importance (Barbour *et al.* 1987).

On 8 and 15 September 1994, possible pollinators and herbivores were collected by netting over and hand-collecting from *T. auriculata* plants in four of the sites. Insects captured were transported to the laboratory and identified by Dr. Steven Hamilton, entomologist in the Biology Department, Austin Peay State University. A larval-insect herbivore, observed heavily damaging many plants of *T. auriculata*, was collected and maintained on foliage in the laboratory until pupation when Dr. Hamilton provided identification.

CHAPTER 3

RESULTS AND DISCUSSION

The Study Sites

The seven study sites supporting *Tomanthera auriculata* on the Fort Campbell Military Reservation, Montgomery County, Tennessee, reveal physical similarities in a number of ways: (1) the sites exhibit level to slightly rolling topography; (2) elevations range from 174-186 m with an average elevation of 180 m (U. S. Dept. of the Interior 1957); (3) all sites are underlain by bedrock of the Ste. Genevieve Formation with DsB soil of the Dickson series the most prevalent soil type. The DsB soil approximately accounts for 60 percent of the study site soils. Of the five other represented soils, only MoC2 in the Mountview series accounts for a large portion, approximately 25 percent.

Landscape Modification and Stem Counts

The total stem counts of *T. auriculata* in September 1994, were in excess of 3,800. The same counts, made in September 1995, showed that the population had decreased to less than one-half of that of the prior year, approximately 1,500. One explanation for this decrease is the three-year burn cycle for fields at FCMR to maintain a level of openness for military operations. Based on habitat descriptions for *T. auriculata*, the consistent burn program at FCMR should help to continually provide disturbed areas for growth and seedbed maintenance. Table 1 represents the total *T. auriculata* counts made at each subsite in September 1994 and 1995, and the corresponding burn dates. It was expected that September counts after a spring burn in the same year would be more substantial than counts in the following year(s). While this expected pattern held true for subsites 1-6, the population increases following a spring burn varied greatly.

Table 1. *Tomanthera auriculata* stem counts, September 1994-1995, at Fort Campbell Military Reservation with burn years.

Subsites	1994	1995	Spring Burns
1	1,926	47	1994
2	604	746	1995
3	370	17	1994
4	800	296	1994
5	~75	38	1994
6	~30	329	1995
7	92	91	1995*

*partial burn

The lack of population-size change in subsite 7 could be due to an incomplete burning of the field to which subsite 7 belongs. Bush-hogging is a known, but random and undocumented occurrence in the fields, as is the use of heavy equipment and training maneuvers. The mechanical and burn disturbances also may affect *T. auriculata's* unknown host plant(s), thereby complicating reasons for the variable counts between years.

Flora and Floristic Summary

The floristic list (appended) shows that the flora of the seven subsites, based on sampling data, consists of 23 families, 56 genera, and 77 species. Only 4 species (5.2%) are non-native. Three families, the Asteraceae (20 taxa), Poaceae (13 taxa), and Fabaceae (10 taxa), comprise 55.8 percent of the flora. The major genera are *Lespedeza* (4 species), *Aristida* (3 species), *Aster* (3 species), and *Helianthus* (3 species).

Community Coefficients

The Sorensen community coefficients (Table 2) show a high degree of similarity between the subsites (avg. = 57.51, range = 44.4 - 66.7). Only 14.3 percent of the 21 comparisons have a

Table 2. Sorensen's community coefficients for the seven population subsites supporting *Tomanthera auriculata* at Fort Campbell Military Reservation.

Stand	2	3	4	5	6	7
1	62.8	61.5	54.3	45.5	49.2	44.4
2		57.5	72.3	58.8	53.7	55.4
3			53.3	60.0	57.6	52.6
4				66.7	61.3	60.0
5					59.6	66.7
6						54.5

similarity of less than 50 percent. Of the 85.7 percent with a higher degree of similarity, 38.1 percent have a similarity greater than 60 percent. According to Barbour *et al.* (1987), values greater than 50 percent indicate that different sampling units belong to the same community type. Therefore, it can be inferred that the *Tomanthera auriculata* subpopulations at FCMR are part of the same community type.

Presence

Table 3 indicates that the *T. auriculata* subpopulations at FCMR do not closely follow the normal presence class distribution (Oosting 1956). Presence classes 2-5 contain 65 percent

Table 3. Percent of species from the seven *Tomanthera auriculata* subsites at Fort Campbell Military Reservation in each presence class (1 = 1-20% of subpopulations, 2 = 21-40%, 3 = 41-60%, 4 = 61-80%, 5 = 81-100%) and a *normal distribution (Oosting 1956).

Presence Class	Normal Distribution(%)	FCMR Distribution(%)
1	56.0	35.0
2	16.0	19.0
3	9.3	13.0
4	9.3	16.0
5	9.3	17.0

*approximated from diagram

rather than the normal 45 percent of the species. Significantly, presence class 5 (~constantly present) and presence class 4 (usually present) far exceed the norms. More species with higher presence points to a high degree of similarity in stands comprising the FCMR *T. auriculata* community. A presence table for the known flora of the seven subsites is given in Appendix 2.

Frequency

Table 4 shows the expected or normal percentages for each frequency class versus the actual percentages. While the frequency class distribution for the FCMR populations is more skewed toward FC A and thus seems to indicate a lack of cohesiveness among the plant associates, the presence class distributions are higher than expected in presence classes 3, 4, and 5 (Table 5), thereby indicating a more stable community structure profile. Frequency class E is important for its suggestion of possible host taxa for *T. auriculata*. This class contains *Schizachyrium scoparium* and *Helianthus occidentalis*, both of which occur in 100 percent of the plots.

Community Structure

Based on importance values (IV)(Table 6), the plant community harboring *T. auriculata* at the FCMR is dominated in part by the 13 species in presence class 5 which are among the top

Table 4. Percent of species from the 120 *Tomanthera auriculata* plots at Fort Campbell Military Reservation in each frequency class (A = 1-20%, B = 21-40%, C = 41-60%, D = 61-80%, E = 81-100%) with the *normal FC distribution (Oosting 1956).

Frequency Class	Normal Distribution(%)	FCMR Distribution(%)
A	52	84
B	15	8
C	9	4
D	8	1
E	16	3

*approximated from diagram

Table 5. Presence class distribution (5 = 81-100%, 4 = 61-80%, 3 = 41-60%, 2 = 21-40%, 1 = 1-20%) for species in the seven *Tomanthera auriculata* subsites, Fort Campbell Military Reservation.

Taxa	Presence Classes				
	5	4	3	2	1
Agalinis tenuifolia	x				
Aster dumosus	x				
Chamaecrista fasiculata	x				
Desmodium ciliare	x				
Diodia teres	x				
Helianthus occidentalis	x				
Lespedeza procumbens	x				
Lespedeza stipulacea-striata	x				
Lespedeza virginica	x				
Potentilla simplex	x				
Pycnanthemum tenuifolium	x				
Schizachyrium scoparium	x				
Solidago nemoralis	x				
Ambrosia bidentata		x			
Aster linariifolius		x			
Chamaecrista nictitans		x			
Coreopsis major		x			
Fragaria virginiana		x			
Hypericum gentianoides		x			
Polygala verticillata		x			
Rhus copallina		x			
Rubus flagellaris		x			
Scleria pauciflora		x			
Smilax glauca		x			
Strophostyles umbelata		x			
Aster pilosus			x		
Eragrostis spectabilis			x		
Eupatorium hyssopifolium			x		
Helianthus hirsutus			x		
Hypericum drummondii			x		
Linum virginianum			x		
Liatris squarrosa			x		
Lonicera japonica			x		
Pycnanthemum pilosum			x		
Rosa carolina			x		
Agalinis fasiculata				x	
Aristida dichotoma				x	
Aristida purpurascens				x	
Diospyros virginiana				x	
Gnaphalium purpureum				x	

Taxa	Presence Classes				
	5	4	3	2	1
Gymnopogon ambiguus				x	
Houstonia purpurea				x	
Lobelia puberula				x	
Panicum laxiflorum				x	
Polygala incarnata				x	
Sassafras albidum				x	
Solidago juncea				x	
Sorghastrum nutans				x	
Spiranthes lacera				x	
Tridens flavus				x	
Achillea millefolium					x
Allium vineale					x
Ambrosia artemisiifolia					x
Aristida oligantha					x
Bidens polylepis					x
Buchnera americana					x
Conyza canadensis					x
Desmodium sessilifolium					x
Digitaria sanguinalis					x
Elymus virginicus					x
Eupatorium altissimum					x
Euphorbia corollata					x
Galium pilosum					x
Gaura biennis					x
Helianthus mollis					x
Hieracium gronovii					x
Lespedeza cuneata					x
Liatris squarrulosa					x
Oxalis stricta					x
Panicum depauperatum					x
Passiflora incarnata					x
Prunella vulgaris					x
Rhus glabra					x
Setaria parviflora					x
Symphoricarpos orbiculatus					x
Tephrosia virginica					x
Trichostema dichotomum					x

Table 6. Ranked importance values (IV) for species from the seven *Tomanthera auriculata* subsites at Fort Campbell Military Reservation with IV's greater than 0.999.

Taxa	IV Value	Rank
Schizachyrium scoparium	16.115	1
Helianthus occidentalis	14.625	2
Solidago nemoralis	6.402	3
Potentilla simplex	5.157	4
Agalinis tenuifolia	4.995	5
Lespedeza virginica	3.614	6
Diodia teres	3.494	7
Desmodium ciliare	3.484	8
Lespedeza stipulacea-striata	3.306	9
Aster dumosus	3.100	10
Chamaecrista nictitans	2.850	11
Lespedeza procumbens	2.440	12
Chamaecrista fasiculata	1.952	13
Coreopsis major	1.709	14
Ambrosia bidentata	1.662	15
Smilax glauca	1.662	15
Solidago juncea	1.298	16
Rosa carolina	1.237	17
Pycnanthemum tenuifolium	1.206	18
Aster linariifolius	1.174	19
Helianthus hirsutus	1.044	20
Rubus flagellaris	1.008	21

18 rankings. The 77 plant associates' ranked IV's range from 1 to 36, with 28.6 percent, or rank numbers 1-21 having IV's greater than 0.999. The two species with 100 percent frequencies in all 120 plots are *Schizachyrium scoparium* and *Helianthus occidentalis*; these species have IV's of 16.115 and 14.625 and rank 1 and 2, respectively. Rank 3, *Solidago nemoralis*, drops to 6.402 IV and only occurs in 60.8 percent of the plots (frequency class D). Replicate experiments by Cunningham and Parr (1990) showed *Helianthus occidentalis* to be a successful host for *T. auriculata*. *Schizachyrium scoparium* was not part of this host experiment, but data here indicate a high possibility that this species is a host species.

Pollinators/Herbivores

Most of the insects captured on *T. auriculata* plants are species of bees and beetles functioning as pollinators (Table 7). The only certain herbivorous insect caught is the caterpillar of *Precis coenia*, the buckeye butterfly, which is known to feed on species of *Gerardia* (former generic synonym of *T. auriculata*)(Klots 1951). Heavy herbivorous activity characterized by large bite marks is attributed to deer known to inhabit the area. However, predation does not appear to be a limiting factor for this population. Even predated plants usually produced flowers and fruit with seeds.

Table 7. Insects captured from *Tomanthera auriculata* plants in three subsites at Fort Campbell Military Reservation on 8 and 15 September 1994, and possible relationships between the insects and plants.

Order	Family	Genus species/common name	Function
Coleoptera	Chantharidae	*Chauliognathus* poss. *pennsylvanicus*/goldenrod soldier beetle	pollen feeder
	Chrysomelidae	*Diabrotica unidecimpunctata*/spotted cucumber beetle	nectar or pollen feeder
Diptera	Syrphidae	unknown	nectar feeder
Hemiptera	Pentatomidae	*Oebalus pugnax*/rice stink bug	
Hymenoptera	Anthophoridae	unknown	all insects collected in Hymenoptera likely nectar feeders & pollen collectors
	Apidae	*Xylocopa* sp./carpenter bee	
		Apis mellifera/honey bee	
		Bombus sp./bumble bee	
	Halictidae	*Lassioglossum* sp./sweat bee	
	Megachilidae	*Megachile* sp.	
Lepidoptera	Arctiidae	*Cisseps fulvicollis*/yellow-collared scape moth	nectar feeder
	Nymphalidae	*Precis (Junonia) coenia*/buckeye butterfly	herbivore (collected as caterpillar)

CHAPTER 4

SUMMARY

Based on published reports, the seven fluctuating subpopulations of *Tomanthera auriculata* (Michaux) Rafinesque (Scrophulariaceae) at the Ft. Campbell Military Reservation barrens, Montgomery County, Tennessee, are among the largest in existence. The seven subsites exhibit strong similarities in topography (level to slightly rolling), elevations (174-186 m above sea level), bedrock (Ste. Genevieve Limestone), and soils (Dickson series prevalent). The typical habitat for *T. auriculata* generally corresponds to some type of disturbance, and this site is very obliging with regular burning schedules, training maneuvers, *etc.* While stands of *T. auriculata* were often found in fairly small areas regardless of amount of suitable space, the plant was predictably absent from thicker, taller, and scrubbier stands. There was some bare ground in 48.1% of the 120 quadrat plots taken. This is all indicative of the need for more disturbed sites which is at least partially due to the seeds' light requirement for germination.

Total stem counts in September 1994, revealed a population of about 3,900 plants. In September 1995, the population had decreased to about 1,564. Population numbers increased greatly in two subsites burned in March 1995 (634 to 1075), decreased in four sites not burned (3171 to 398), and remained about the same in the one site that received a partial burn (92 to 91).

The flora of the seven subsites, based on sampling data, consist of 23 families, 56 genera, and 77 species (4 non-native). The subsites are related at an average Sorensen's community coefficient of 57.51. There are more species in presence classes 4 and 5 than normally found (33% versus 18.6%). Frequency data, based on 120 m^2 quadrats distributed over the seven subsites, are inconclusive, except that only two species, *Schizachyrium scoparium* and *Helianthus occidentalis*, occurred in all sampling plots. Inconclusive frequency data for even some of the

most prevalent species does not necessarily diminish the stability of the community structure profile since the plots, containing *T. auriculata,* and therefore disturbed habitat by definition, were often sparse with some bare ground.

Based on importance values (relative frequency plus relative cover), the seven subsites are dominated by *Schizachyrium scoparium*, little bluestem (16.12 of IV 200) and *Helianthus occidentalis*, sunflower (14.63 of IV 200). These two species were constant associates of *T. auriculata*, and may well serve as host taxa for the hemiparasite.

Predation on plants in this population was minimal, although the larval stage of the buckeye butterfly often damaged some plants.

This study indicated that burning and/or other habitat modifications are required to maintain a healthy population of *T. auriculata* at this site. Further studies are required to elucidate the extent and kinds of habitat modifications required.

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APPENDICES

Appendix 1. Categorized list of taxa with number of plot occurrences in the seven *Tomanthera auriculata* subsites, Fort Campbell Military Reservation.

An asterisk indicates a non-native taxon.

ANGIOSPERMS--MONOCOTYLEDONS

Cyperaceae
Scleria pauciflora Muhl. ex Willd. [7]
Liliaceae
**Allium vineale* L. [1]
Orchidaceae
Spiranthes lacera (Raf.) Raf. var. *gracilis* (Bigelow) Luer [3]
Poaceae
Aristida dichotoma Michx. [3]
Aristida oligantha Michx. [2]
Aristida purpurascens Poir. [3]
**Digitaria sanguinalis* (L.) Scop. [1]
Elymus virginicus L. [6]
Eragrostis spectabilis (Pursh) Steud. [8]
Gymnopogon ambiguus (Michx.) Britton, Sterns & Poggenb. [3]
Panicum depauperatum Muhl. [2]
Panicum laxiflorum Lam. [3]
Schizachyrium scoparium (Michx.) Nash [120]
Setaria parviflora (Poir.) Kerguelen [1]
Sorghastrum nutans (L.) Nash [4]
Tridens flavus (L.) Hitchc. [5]
Smilacaceae
Smilax glauca Walter [20]

ANGIOSPERMS--DICOTYLEDONS

Anacardiaceae
Rhus copallina L. [11]
Rhus glabra L. [2]
Asteraceae
Achillea millefolium L. [1]
Ambrosia artemisiifolia L. [8]
Ambrosia bidentata Michx. [20]
Aster dumosus L. [69]
Aster linariifolius L. [14]
Aster pilosus Willd. [6]
Bidens polylepis S. F. Blake [2]
Conyza canadensis (L.) Cronq. [2]
Coreopsis major Walter [21]
Eupatorium altissimum L. [1]
Eupatorium hyssopifolium L. [4]

Gnaphalium purpureum L. [2]
Helianthus hirsutus Raf. [12]
Helianthus mollis Lam. [2]
Helianthus occidentalis Riddell [120]
Hieracium gronovii L. [1]
Liatris squarrosa (L.) Michx. [8]
Liatris squarrulosa Michx. [5]
Solidago juncea Aiton [16]
Solidago nemoralis Aiton [73]
Campanulaceae
Lobelia puberula Michx. [3]
Caprifoliaceae
**Lonicera japonica* Thunb. [5]
Symphoricarpos orbiculatus Moench [1]
Clusiaceae
Hypericum drummondii (Grev. & Hook.) Torr. & Gray [9]
Hypericum gentianoides (L.) Britton, Sterns & Poggenb. [7]
Ebenaceae
Diospyros virginiana L. [2]
Euphorbiaceae
Euphorbia corollata L. [1]
Fabaceae
Chamaecrista fasciculata (Michx.) Greene [24]
Chamaecrista nictitans (L.) Moench [35]
Desmodium ciliare (Muhl. ex Willd.) DC. [42]
Desmodium sessilifolium (Torr.) Torr. & A. Gray [1]
**Lespedeza cuneata* (Dum. Cours.) G. Don [6]
Lespedeza procumbens Michx. [30]
Lespedeza stipulacea-striata Maxim.-(Thunb.) H. & A. [37]
Lespedeza virginica (L.) Britton [44]
Strophostyles umbellata (Muhl. ex Willd.) Britton [9]
Tephrosia virginiana (L.) Pers. [2]
Lamiaceae
**Prunella vulgaris* L. [1]
Pycnanthemum pilosum Nutt. [3]
Pycnanthemum tenuifolium Schrad. [14]
Trichostema dichotomum L. [1]
Lauraceae
Sassafras albidum (Nutt.) Nees [6]
Linaceae
Linum virginianum L. [6]
Onagraceae
Gaura biennis L. [1]
Oxalidaceae
Oxalis stricta L. [1]
Passifloraceae
Passiflora incarnata L. [1]
Polygalaceae
Polygala incarnata L. [3]

Polygala verticillata L. var. *ambigua* (Nutt.) A.W. Wood [6]

Rosaceae

Fragaria virginiana Duchesne [9]

Potentilla simplex Michx. [63]

Rosa carolina L. [15]

Rubus flagellaris Willd. [12]

Rubiaceae

Diodia teres Walter [43]

Galium pilosum Aiton [1]

Houstonia purpurea L. [3]

Scrophulariaceae

Agalinis fasciculata (Elliott) Raf. [2]

Agalinis tenuifolia (Vahl) Raf. [61]

Buchnera americana L. [1]

Appendix 2. Presence list for the 77 taxa found in the seven subsites where *Tomanthera auriculata* is known to occur, Fort Campbell Military Reservation (x = species present).

	Subsites						
Taxa	1	2	3	4	5	6	7
Achillea millefolium	-	-	x	-	-	-	-
Agalinis fasiculata	-	-	x	-	x	-	-
Agalinis tenuifolia	x	x	x	x	x	x	x
Allium vineale	x	-	-	-	-	-	-
Ambrosia artemisiifolia	x	-	-	-	-	-	-
Ambrosia bidentata	x	x	x	x	-	x	-
Aristida dichotoma	-	-	x	-	x	-	-
Aristida oligantha	-	x	-	-	-	-	-
Aristida purpurascens	x	-	x	-	-	-	-
Aster dumosus	x	x	x	x	x	x	x
Aster linariifolius	-	x	x	x	x	-	x
Aster pilosus	x	-	x	-	-	x	-
Bidens polylepis	x	-	-	-	-	-	-
Buchnera americana	-	x	-	-	-	-	-
Chamaecrista fasiculata	x	x	x	x	x	x	x
Chamaecrista nictitans	x	x	x	x	x	-	-
Conyza canadensis	-	-	-	x	-	-	-
Coreopsis major	-	x	x	x	x	-	x
Desmodium ciliare	x	x	x	x	x	x	x
Desmodium sessilifolium	-	x	-	-	-	-	-
Digitaria sanguinalis	-	-	x	-	-	-	-
Diodia teres	x	x	x	x	x	x	x
Diospyros virginiana	-	x	x	-	-	-	-
Elymus virginicus	x	-	-	-	-	-	-
Eragrostis spectabilis	x	x	x	-	-	-	-
Eupatorium altissimum	x	-	-	-	-	-	-
Eupatorium hyssopifolium	-	-	-	x	x	-	x
Euphorbia corollata	-	-	-	-	-	x	-
Fragaria virginiana	x	x	x	x	-	-	-
Galium pilosum	-	-	x	-	-	-	-
Gaura biennis	-	-	-	x	-	-	-
Gnaphalium purpureum	-	-	-	x	-	-	x
Gymnopogon ambiguus	x	x	-	-	-	-	-
Helianthus hirsutus	x	x	-	x	-	x	-
Helianthus mollis	-	-	x	x	x	x	x
Helianthus occidentalis	x	x	x	-	-	-	-
Hieracium gronovii	-	-	-	x	-	-	-
Houstonia purpurea	x	-	x	-	x	x	-
Hypericum drummondii	-	x	-	x	x	-	x
Hypericum gentianoides	-	x	-	-	-	x	-
Lespedeza cuneata	x	-	x	x	-	x	x
Lespedeza procumbens	x	x	x	x	x	x	x
Lespedeza stipulacea-striata	x	x	x	x	x	x	-
Lespedeza virginica	x	x	x	x	x	x	x

Taxa	Subsites						
	1	2	3	4	5	6	7
Linum virginianum	-	-	x	-	x	-	x
Liatris squarrosa	-	x	-	x	-	-	x
Liatris squarrulosa	x	-	-	-	-	-	-
Lobelia puberula	-	-	x	-	-	x	-
Lonicera japonica	x	x	-	-	-	-	x
Oxalis stricta	-	-	-	x	-	-	-
Panicum depauperatum	-	x	-	-	-	-	-
Panicum laxiflorum	-	-	-	x	-	x	-
Passiflora incarnata	x	-	-	-	-	-	-
Polygala incarnata	-	-	x	x	-	-	-
Polygala verticillata	-	x	-	x	x	x	-
Potentilla simplex	x	x	x	x	x	x	-
Prunella vulgaris	-	x	-	-	-	-	-
Pycnanthemum pilosum	x	x	-	x	-	-	-
Pycnanthemum tenuifolium	x	x	x	x	x	x	x
Rhus copallina	x	x	-	x	x	-	x
Rhus glabra	-	-	-	x	-	-	-
Rosa carolina	x	x	-	x	-	-	-
Rubus flagellaris	x	x	x	-	-	-	x
Sassafras albidum	-	x	-	x	-	-	-
Schizachyrium scoparium	x	x	x	x	x	x	x
Scleria pauciflora	-	x	-	x	-	x	x
Setaria parviflora	x	-	-	-	-	-	-
Smilax glauca	x	x	x	x	-	x	-
Solidago juncea	x	x	-	-	-	-	-
Solidago nemoralis	x	x	x	x	x	x	x
Sorghastrum nutans	-	x	x	-	-	-	-
Spiranthes lacera	x	-	x	-	-	-	-
Strophostyles umbelata	x	x	-	x	x	-	-
Symphoricarpos orbiculatus	x	-	-	-	-	-	-
Tephrosia virginica	-	x	x	-	-	-	-
Trichostema dichotomum	-	x	-	-	-	-	-
Tridens flavus	x	-	x	-	-	-	-

VITA

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