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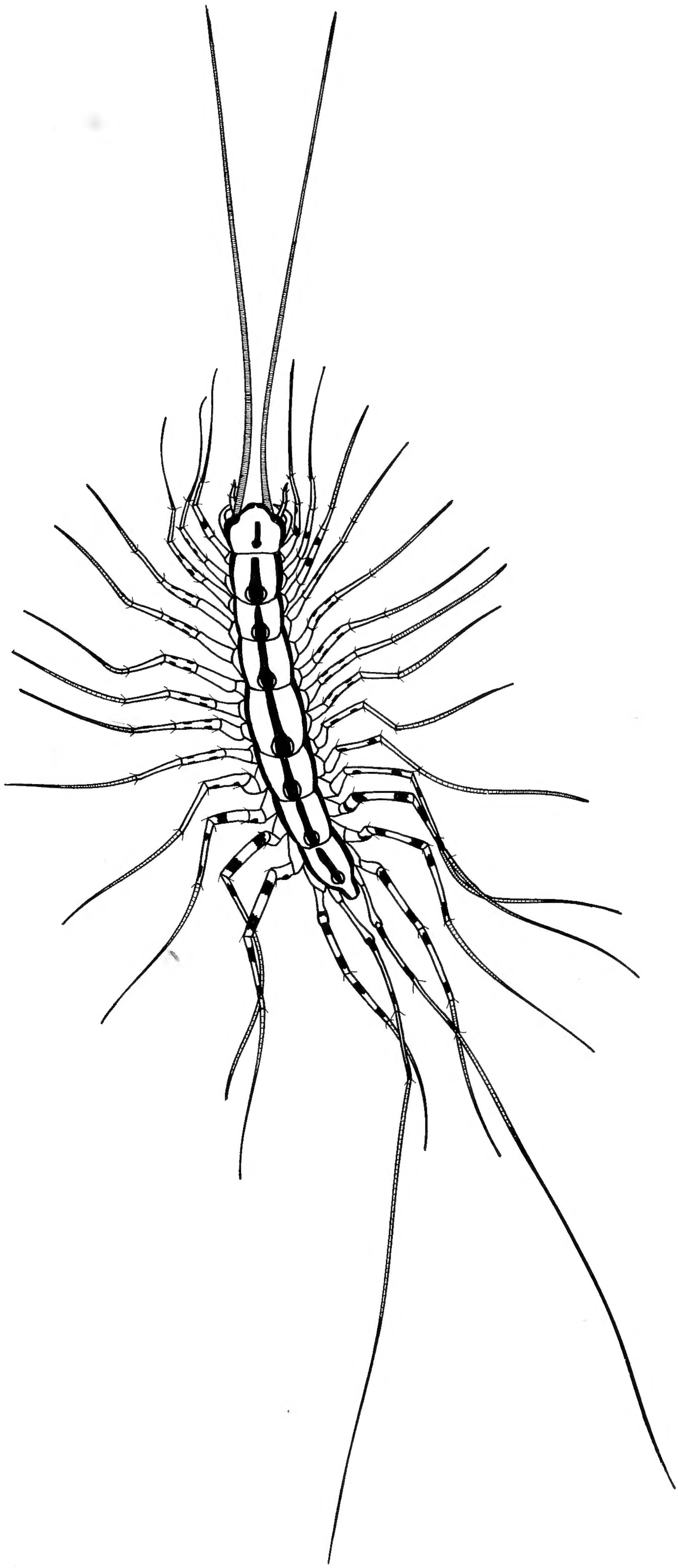

Frontispiece. The house centipede (*Scutigera coleoptrata*) Drawing by Scott L. Stauber. See article starting on page 1.

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The House Centipede (*Scutigera coleoptrata*; Chilopoda): Controversy and Contradiction

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I objurgate the centipede,
A bug we do not really need.
At sleepy-time he beats a path
Straight to the bedroom or the bath.
You always wallop where he's not,
Or if he is he makes a spot.

—Ogden Nash[1]

ABSTRACT

The common house centipede, *Scutigera coleoptrata*, has a long and storied history in the annals of zoology. The species has been through five scientific name changes since it was first described by Linnaeus in 1758. Its widespread distribution throughout the Northern Hemisphere has resulted in substantial debate as to its place of origin. Among the centipedes, its morphology is unique and highly specialized, including compound eyes, elongated legs for sprinting, and posterior legs that function as rear antennae. It is a formidable and efficient predator, which sets it apart from others in the Chilopoda. The highly adaptable *S. coleoptrata* thrives in human habitation, and as such, is referred to as the house centipede despite the fact that its natural habitat is in moist crevices and detritus on forest floors. House centipedes may well reign as the ultimate house cleaners, preying on a multitude of invasive invertebrates. Nevertheless, it is still considered a pest to humans and has become a prime target of the pest control industry. This review summarizes some interesting aspects of the biology and ecology of *S. coleoptrata*, with focus on records from North America.

INTRODUCTION

Ogden Nash's irreverent ode to the lowly centipede seemed unjustly aimed at the house centipede, *Scutigera coleoptrata* (Frontispiece). The house centipede is a common member of the fauna of many households throughout the United States and Canada, and it is one of three species of centipedes found in Kentucky. Its natural habitat in the Ohio region is under moist rock ledges, detritus, and crevices in woodlands (Lee 1980), but it readily adapts to basements, drainage fixtures, and other cool moist environments of human habitations. House centipedes may actually be beneficial to humans because they prey on many household pests, including insects, small spiders, and sow bugs. Yet, a recent search of the Internet using the keywords "centipede AND pest" yielded ca. 35,000 websites of pest management companies and extension agencies that listed the house centipede as a major pest. Along with this seeming contradiction is the controversy on the taxonomic status of house centipedes. Is *S. coleoptrata* a single species or several species? Introduced or native? Friend or foe? These and many other questions remain unresolved, despite the ubiquitous presence of house centipedes in our daily lives.

TAXONOMY AND DISTRIBUTION

The house centipede was originally described as *Scolopendra coleoptrata* by Linnaeus in 1758 in Systema Naturae. The same species was subsequently re-described variously as *Selista forceps* (Rafinesque 1820), *Cermatia coleoptrata* (Say 1821), *Scutigera forceps* (Meinert 1885), and finally as *Scutigera coleoptrata* (Pocock 1893). It was described as *S. coleoptrata* in the 1928 Ohio Biological Survey (Williams and Hefner 1928). House centipedes have large heads, prominent compound eyes, long annulated antennae, and very long legs. The body is 25–30 mm long, but total length may be 150 mm from tip of antenna to tip of the last leg. Body coloration is variable, ranging from olive green to yellow. Three longitudinal lines of green, blue, violet, or black run the length of the body, and the legs have black rings.

The current taxonomy of the genus *Scutigera* contains this single North American species. *Scutigera coleoptrata* (Chilopoda: Scutigeromorpha) is a member of a suite of 130 species in the Family Scutigeridae, most of which are tropical. The most reliable records suggest that the house centipede may be native to the Mediterranean region, but it is common throughout Europe, Asia, and much of North America supposedly as a consequence of introductions. There are many anecdotal references to the house centipede introduced to the United States from Mexico, but this has not been substantiated. However, its presence has been systematically documented from the southern states through Massachusetts by 1890 to southern Canada in 1914 (Hewitt 1914), suggesting that the species' range is spreading. The possibility remains that the species was always native to these various locations where it was simply being systematically documented for the first time. It is now considered common from the east coast of the United States to the Rocky Mountains and has been recorded as far west as Washington state (Johnson 1952).

MORPHOLOGY AND PHYSIOLOGY

Scutigerid centipedes have a distinctive anatomy quite unlike that of other Chilopoda. The body shape is not dorso-ventrally flattened but is more rounded, similar to the Diplopoda. The head capsule is hemispherical with laterally-placed, multiarticulated antennae. The dome-shaped head houses very large mandibles that Manton (1964) considered to be the most specialized and advanced in the Chilopoda. The coxosternite of the first maxillae has regions covered with hair and spindle processes that serve as grooming structures for cleaning the antennae and legs. The forcipules contain poison glands that discharge via ducts behind the tip of the claw.

The antennae of the house centipede are long with up to 300 annulations. The basal segment of the antennae bears openings to the chemosensory Schaftorgan. Behind the antennae is a pair of modified compound eyes, in contrast to other chilopods which have simple ocelli. Small Tömösvary organs are located between the antennae and eyes. While the precise function of the Tömösvary organs is still unclear, there is contradictory indications that they function as auditory (Meske 1961), humidity (Tichy 1973), or olfactory receptors (Lewis 1981).

There are 15 body segments with paired legs, but the terga are fused into seven plates. The 15 pairs of legs are extraordinarily long, increasing in length from anterior to posterior. The coxa are well developed with a ventral spine, but the trochanter is greatly reduced (Manton 1965). The prefemur, femur, and tibia bear longitudinal rows of teeth and terminate with three long spines. The tarsus contains up to 500 annulations and terminates with an apical claw. The annulations of the tarsus bear ventral setae and pegs used to firmly grip the substratum. Each leg is powered by at least 34 separate muscles, compared to two in other centipedes (Manton 1965). The first 14 pairs of legs are used for running, each bearing an equal load. The last pair of legs is directed posteriorly and does not appear to function for locomotion but instead may serve as "rear antennae." Scutigerids are sometimes observed resting under leaves or debris with both antennae and rear legs left out to monitor their surroundings.

Regeneration in *S. coleoptrata* is a highly ordered and efficient process. Legs that are lost are usually replaced in fully-developed form after one molt (Cameron 1926). If the loss of legs does not hamper mobility significantly, house centipedes molt in the normal 30 to 60 day cycle, depending on ambient temperature. However, the loss of all legs may decrease the molting interval by half. Cameron (1926) suggested that the long legs helped to prevent predators from reaching the vulnerable body, and autotomy of legs reduced mortality due to predation. Legs can be autotomized instantly, and autotomized legs continue to twitch for several minutes. In the tropical species *S. decipiens* from the caves of Malaysia, autotomized legs produce loud stridulating sounds (Lewis 1981). This is a particularly effective distraction for reducing the impacts of predatory attacks.

The seven tergites each bear a median dorsal spiracle for gas exchange, unlike the lateral paired spiracles of other myriapods. The spiracles lead to regularly branching tracheal tubes that terminate near the pericardial cavity where they are bathed by blood. The blood contains the respiratory pigment hemocyanin, also unique among the myriapods (Hilken 1997; Mangum et al. 1985). The lung-like tracheal system and efficient oxygen uptake by hemocyanin, aided by active ventilatory compressions from 90 to 200 beats/min., may be adaptations for high-speed movement during flight from predators or in pursuit of prey.

Male scutigerids have differentiated macrotestes that produce large sperm and microtestes that produce small sperm (Bouin 1934). This process of double spermatogenesis produces sperm that are different in number of organelles and size, including tails up to 3.5 mm long on the macrosperm (Mazzini et al. 1992). However, there are no differences in DNA content (Prunescu et al. 1995). The functional significance of double spermatogenesis in scutigerids is still unknown.

Females lay relatively few eggs (average four eggs per day; Lewis 1981), singly in soil. Laying and hatching occurs from late spring through early summer. The first instar larva hatches with 4 pairs of legs, then via subsequent molts, increases to 5, 7, 9, 11, and finally 15 pairs of legs (Verhoeff 1938a) (Figure 1). The first two larval stages lack tracheae and feed on stored yolk reserves, but the third larval stage is well developed and preys on springtails and small spiders. Knoll (1974) suggested that patterns of early development of *S. coleoptrata* is more similar to development in primitive insects than to the scolopendromorph centipedes. Maturity is attained following the eighth molt. The maximum life span is estimated to be 3 years.

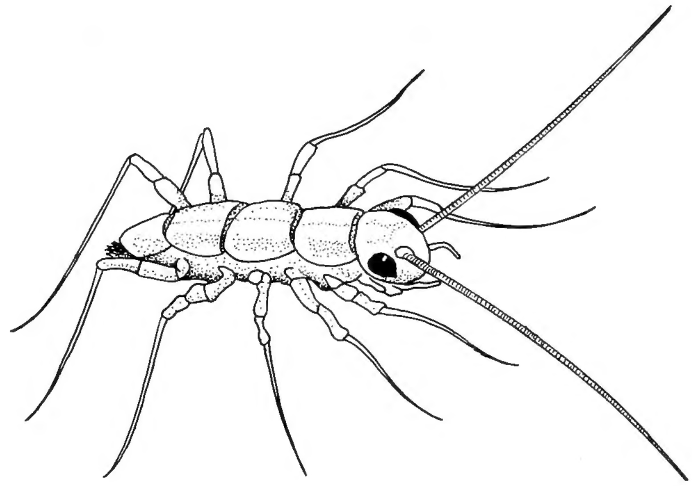

Figure 1. House centipede, *Scutigera coleoptrata*. The second instar has five pairs of running legs but lacks feeding mouthparts. At this stage, the larva still relies upon stored yolk reserves for food. Redrawn by by Scott L. Stauber from Knoll (1974).

BEHAVIOR AND ECOLOGY

The well-developed compound eyes of scutigerids are unique among Chilopoda. Each modified compound eye lacks crystalline cones but contains 100 to 200 highly ordered ocelli that converge to form optic rods (Paulus 1979). The highly convex corneal lens may aid in image formation, similar to the compound eyes of insects and crustaceans. This advanced level of vision may be another adaptation to rapid pursuit of mobile prey. Le Moli (1970) suggested that *S. coleoptrata* was able to visually distinguish between certain mutant types of the fruit fly *Drosophila melanogaster.*

House centipedes meticulously groom themselves on a strict schedule (Le Moli and Parmigiani 1976). The antennae and legs are gripped by the forcipules and passed through the cleaning setae on the first maxillae (Verhoeff 1938b). Particular attention is paid to cleaning the tarsi of legs 1 through 6. Grooming activity starts with an antenna, followed by legs 1 through 15 of the same side. Appendages on the other side are then cleaned in the same order. If an individual is interrupted for any reason during grooming, cleaning commences where the individual left off prior to being disturbed. Conflict situations (competitors, potential mates, environmental disturbance) result in a significant increase in grooming activity, referred to as displacement activity by Le Moli and Parmigiani (1976). Grooming behavior appears to be genetically hard-wired because house centipedes will still attempt to clean legs that have been amputated.

House centipedes are deadly and efficient predators. But compared to many other centipede species, the venom of the poison glands of *S. coleoptrata* is far less toxic, at least to humans. Description of bites range from "severe pain" (Herms 1939) to a "minor nuisance" (Johnson 1952), but more serious consequences are most likely due to secondary infections rather than the bite itself (Ewing 1928). However, the house centipede is deadly to many common invertebrates including flies, silverfish, moths, cockroaches, termites, bees, wasps, sowbugs, and spiders (Cameron 1926; Johnson 1952; Verhoeff 1938b). They are also known to kill other centipedes including *Bothropolys* and *Lithobius*, as well as other scutigerids. Newly molted male house centipedes are especially susceptible to predation by females. The long legs of *S. coleoptrata* function primarily for chasing and catching mobile prey. House centipedes are the greyhounds of the Myriapoda. They have been clocked at 420 mm/sec with a 33 mm stride, which was impressive enough to be listed as among the fastest arthropods in the 1973 Guinness Book of World Records. The long, flexible legs also serve to hold multiple prey securely while one prey item is being leisurely consumed (Johnson 1952).

SUMMARY

Among the Chilopoda, scutigerids appear to be an anomaly. The spider-like body with long legs is built for speed and agility. The setae and pegs of leg segments provide traction. The hemocyanin pigment in the blood efficiently supplies oxygen for fast sprinting. The modified compound eyes may enable acute vision necessary for quickly discerning prey types. The forward antennae and sensory structures of the last pair of legs monitor all activity in the surrounding environment. Autotomy of legs provide distraction for predators but not for the house centipede itself. *Scutigera coleoptrata* is a superbly designed predator that thrives in its natural habitat as well as in human habitats. Curran (1946) referred to house centipedes as "uninvited guests in the house," and pest managers have embraced this designation. But it is clear that house centipedes are far more beneficial than harmful in human domiciles.

A number of questions about this species remain unresolved. Is its distribution really a result of human-facilitated introductions throughout much of its range, or is the present distribution a result of natural large-scale biogeographic processes? What is the function of dimorphism in spermatogenesis? Is the functional morphology simply a highly specialized adaptation to a predatory lifestyle? Is this the sole reason why the house centipede is so radically different from other chilopods? Is its domestic ecology substantially different from its natural ecology? At closer inspection, the lowly house centipede certainly appears to be much more than a mere annoyance in Ogden Nash's imagination.

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Modification of Index of Biotic Integrity for Russell Fork of Upper Big Sandy River System, Kentucky

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ABSTRACT

A bioassessment of eight sites on the mainstem Russell Fork (Big Sandy River–Ohio River) was conducted in 1998. Nine collections of fishes were made following Kentucky Division of Water protocol (KDOW). Index of Biotic Integrity (IBI) metrics modified by KDOW for use in the Western Allegheny Ecoregion (WAE) were used for analysis in the absence of Central Appalachian Ecoregion (CAE) metrics. The mean score of the nine collections was 55.3 (good to excellent) and two collections scored a perfect 60 (excellent). Coal mining, logging, construction, and organic pollution observed within the watershed and the probable extirpation of two fishes indicated that these scores did not accurately reflect water quality in the Russell Fork. Three of the metrics were modified in an attempt to more accurately assess the Russell Fork water quality. After modification, the mean score was 51.8 (good) and the highest score for any one site was 58 (excellent).

INTRODUCTION

In an effort to assess the health of stream systems, researchers have analyzed fish communities by use of the Index of Biotic Integrity (IBI). The IBI, originally developed by Karr (1981) for use in Illinois streams, was modified into a more complete tool by Karr et al. (1986). By use of the IBI, samples of fish communities are analyzed through 12 equally weighted metrics. Each metric is assigned a score of 1, 3, or 5 with 5 approximating an unimpacted condition. Therefore a perfect score of 60 should indicate a pristine stream that has not suffered from human impacts. Because different states and physiographic regions have different fish faunas, metrics developed in one region may be inaccurate for use in another; thus the IBI was modified by Kentucky Division of Water (KDOW 1997) for use in Kentucky streams. However, IBI scoring metrics were not modified for use in all Kentucky ecoregions. Metrics for use in the Central Appalachian Ecoregion (CAE) of eastern Kentucky have not been developed. Data points for the upper Cumberland and Kentucky river drainages in CAE were plotted, but no values indicating scoring criteria were developed. Furthermore, no data points were plotted for any sites in the Big Sandy River drainage.

Superficial evaluation of the ichthyofauna of the forks of the Big Sandy River system (Burr and Warren 1986; Jenkins and Burkhead 1994) indicated that the least impacted drainage in the Big Sandy River system is the Russell Fork. The ichthyofauna of the Kentucky portion of the Russell Fork is rich, with 67 species, and typical of an Appalachian Plateau stream (Powers and Ceas 2000).

The Russell Fork originates in Dickenson County, Virginia, and flows northwestward into Kentucky. In Kentucky, it is a typical medium-sized Appalachian stream with clearly defined riffles, runs, and pools (Kirkwood 1957; Powers and Ceas 2000). Substrate in the Russell Fork is also typical of an Appalachian stream with boulder to cobble riffles giving way to sand- and silt-bottomed pools (Burr and Warren 1986). The Russell Fork flows 28 rkm in Kentucky and is a sixth order tributary to the Levisa Fork.. The entire drainage lies within the CAE and drains all of Dickenson County, Virginia, parts of Buchanan and Wise counties, Virginia, and Pike County, Kentucky (Jenkins and Burkhead 1994; KDOW 1997).

Land within the Russell Fork drainage has been a source of coal and timber for over 100 years (Jenkins and Burkhead 1994). Agricultural and residential development in the Russell Fork drainage is limited by the rugged terrain of the area but concentrated near stream banks in the narrow valleys of Russell Fork tributaries. Mining, logging, agriculture, and domestic pollution have probably caused a decrease in biodiversity of the Russell Fork (Burr and Warren 1986; Powers and Ceas 2000).

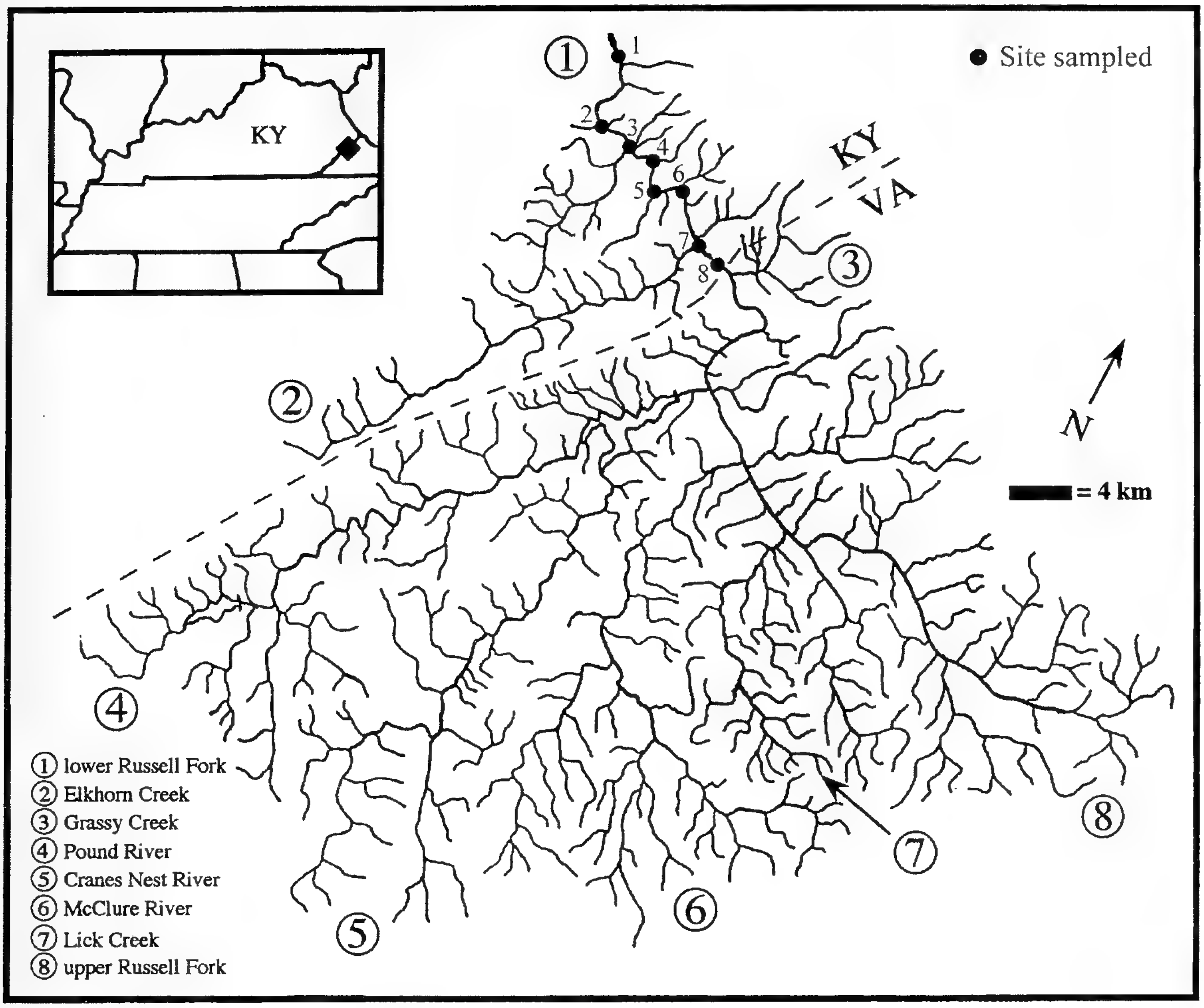

Figure 1. Map of Russell Fork drainage with major tributaries and localities sampled in Pike County, Kentucky during 1998.

The objectives of this study were as follows:

1. Assess the biotic integrity of the Kentucky portion of the Russell Fork using IBI metrics developed for the nearest available ecoregion.
2. Determine if those metrics are accurate for bioassessment within the drainage.
3. Suggest alterations to the metrics to make them more accurate for use in the Russell Fork and possibly other streams in the Big Sandy River system.

METHODS

Nine collections were made from the following eight localities (Figure 1) in the Pike County, Kentucky, portion of the mainstem Russell Fork during 1998: (1) near Winwright Station off US Hwy 460, 14 August and 6 November; (2) 3 km nw of Marrowbone at bridge off US Hwy 460, 13 August; (3) near Marrowbone off US Hwy 460, 13 August; (4) 2 km n Draffin along dirt road off Pond Creek Rd., 14 August; (5) near Draffin at Pond Creek Rd. bridge, 25 August; (6) 2 km se Draffin upstream of bridge off US Hwy 460, 13 August; (7) in Elkhorn City at KY Hwy 80 bridge, 25 July; and (8) 3 km se Elkhorn City at river access off KY Hwy 80, 14 August. Sampling was done following a protocol outlined by KDOW (1993). This required sampling all available habitats at each site for a total of 1 hr using seines and electrofishing. Specimens were retained and preserved in 10% formalin for at least 1 wk, rinsed in tap water, and transferred into 70% ethanol for long-term storage. Fishes were identified using Etnier and Starnes (1993) and Jenkins and Burkhead (1994). All specimens were catalogued into the research collection at the Branson Museum of Zoology at Eastern Kentucky University in

Table 1. Western Allegheny Ecoregion IBI scoring criteria for 600 mi² drainage area from KDOW (1997).

Metric	Scoring criteria		
	5	3	1
Total # of species	>17	17–8	<8
# of darter species	>5	5–3	<3
# of sunfish species	>1	1	0
# of sucker species	>1	1	0
# of intolerant species	>10	10–5	<5
% tolerant species	<30	30–60	>60
% omnivores	<20	20–50	>50
% insectivores	>55	25–55	<25
# top carnivore species	>1	1	0
# simple lithophils	>8	8–4	<4
% DELT anomalies	<0.1	0.1–1.3	>1.3
# of individuals	>100	50–100	<50

Table 2. Classification scheme of water quality for IBI scores from KDOW (1997).

Classification	Score
Excellent	57–60
Good	48–52
Fair	39–44
Poor	28–35
Very poor	<23

Richmond, Kentucky. Original sorting sheets were also stored at the Branson Museum.

In the absence of metrics designed for use in CAE, IBI scores were calculated using the Western Allegheny Ecoregion (WAE) metrics (Table 1) and compared to the classification scheme for water quality corresponding to IBI scores (Table 2) (KDOW 1997). These metrics were used due to the proximity and similarity of ichthyofauna of the WAE to the CAE. Both ecoregions are also drained by tributaries to the Ohio River system.

To determine if the WAE metrics were accurate indicators of stream health in the CAE, qualitative information such as change in fauna over time and human disturbance of the drainage basin was evaluated. Scores from this study (Table 3) were compared to an IBI study done in a relatively unimpacted portion of the WAE during the same time period (Ray 1999). When inconsistencies between qualitative information and IBI scores were noted, metrics were changed. Alterations of metrics were based on protocol used by KDOW to establish scoring criterion for other ecoregions (KDOW 1997), making interpretation of the fish data more accurately correspond to qualitative data. Alterations are presented in the "Discussion" section of this paper.

RESULTS

The overall mean IBI score for all collections using WAE metrics was 55.3 (good to excellent). Site three scored a perfect 60 (excellent) as did one of the collections from site one. All sites scored perfect (five) for eight of the 12 metrics: number of species, darter species, number of intolerant, percent tolerant, percent insectivores, number of lithophilic species, percent DELT anomalies, and number of individuals. The lowest score, 46 (fair to good), was for site two. Site two scored one for the metrics sunfish species, sucker species, and number of carnivores. Sites four and six also scored one for sunfish species. Site six also scored one for number of carnivores. Scores for each metric and site are presented in Table 3.

DISCUSSION

Scores Using WAE Metrics

The probable extirpation of at least two species considered intolerant by KDOW (1997), *Ammocrypta pellucida* (eastern sand darter) and *Nocomis micropogon* (river chub) (Powers and Ceas 2000), indicated changes in the Russell Fork fauna in recent years. Descriptions of other authors (Burr and Warren 1986; Jenkins and Burkhead 1994; Robinson and Branson 1980) and my observations of the Russell Fork watershed indicated that there have been human impacts on water quality including extensive siltation from coal mining, logging, construction, and organic pollution. The high mean IBI scores of this study (55.3, good to excellent), perfect scores at sites one and three, and perfect scores for eight of the 12 metrics (Table 3) by all sites indicated that the WAE metrics (KDOW 1997) were not sensitive to disturbances in the Russell Fork. In comparison, a bioassessment of 11 sites in a nearly completely forested watershed in the WAE with very little human disturbance and no recorded extirpations (Sturgeon Creek–Kentucky River) also yielded a mean IBI score of 55.3 (Ray 1999). Furthermore, a similar study at nine sites, one of which is considered a Reference Reach Site by KDOW (1997), in Horse Lick Creek (Rockcastle River) using the

Table 3. IBI scores of Russell Fork, Pike County, Kentucky sites sampled during 1998 using KDOW (1997) Western Allegheny Ecoregion IBI metrics[1]

	Site								
Metric	1°	1°	2	3	4	5	6	7	8
# species	5 (33)	5 (27)	5 (20)	5 (26)	5 (22)	5 (23)	5 (19)	5 (25)	5 (18)
Darter species	5 (9)	5 (7)	5 (6)	5 (7)	5 (7)	5 (9)	5 (9)	5 (10)	5 (7)
Sunfish species	3 (1)	5 (2)	1 (0)	5 (2)	1 (0)	3 (1)	1 (0)	3 (1)	3 (1)
Sucker species	5 (4)	5 (2)	1 (0)	5 (2)	5 (3)	5 (2)	3 (1)	5 (3)	5 (2)
# intolerant	5 (19)	5 (14)	5 (12)	5 (15)	5 (14)	5 (18)	5 (13)	5 (3)	5 (12)
% tolerant	5 (3.1)	5 (6.9)	5 (2.5)	5 (0.6)	5 (1.6)	5 (.01)	5 (2)	5 (15)	5 (3)
% omnivores	5 (18)	5 (18)	3 (22)	5 (8.8)	5 (17)	3 (23)	5 (12)	3 (11)	5 (9)
% insectivores	5 (76)	5 (78)	5 (65)	5 (90)	5 (76)	5 (72)	5 (80)	5 (67)	5 (79)
# carnivores	5 (5)	5 (3)	1 (0)	5 (3)	3 (1)	5 (2)	1 (0)	5 (2)	5 (2)
# lithophils	5 (16)	5 (11)	5 (11)	5 (15)	5 (12)	5 (12)	5 (12)	5 (14)	5 (10)
% DELT	5 (1)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)
# individuals	5 (289)	5 (290)	5 (121)	5 (319)	5 (129)	5 (426)	5 (152)	5 (436)	5 (342)
Total	58	60	46	60	54	56	50	56	58
Overall mean = 55									

[1] Actual values in parentheses.
° Site sampled twice.

same metrics yielded a mean IBI score of 44.6 (fair to good) with no single collection scoring higher than 58 (excellent) (Schuster and McMurray 1998). Horse Lick Creek has been designated a World Bioreserve by the Nature Conservancy and was considered to have excellent water quality by Board and Schuster (1997) in a study of macroinvertebrates.

The seemingly high IBI scores for the Russell Fork may be due to the calibration of WAE metrics for a slightly more lowland streams with inherently different fish assemblages. The Russell Fork has several large cascades and an abundance of bedrock and boulder substrate throughout its length (Powers and Ceas 2000) and likely provides different fish habitat than found in many of the more lowland mainstem large streams in the WAE. Therefore, the WAE metrics do not properly assess the more upland assemblage of the mainstem Russell Fork. For example, tolerant species (KDOW 1997) such as *Pimephales notatus* (bluntnose minnow) and *Lepomis cyanellus* (green sunfish) were not abundant even in the most degraded sections of the Russell Fork drainage (Powers and Ceas 2000). This is likely due to the avoidance of high gradient streams by both species (Etnier and Starnes 1993). Therefore, the different natural fish community assemblage of the CAE requires alteration of WAE metrics for accurate bioassessment.

Modification of Metrics and Reassessment

Karr et al. (1986) suggested that each metric has a range of sensitivity. Since the Russell Fork drains a largely forested area with a largely intact fauna (Powers and Ceas 2000), metrics sensitive in the low biotic integrity range are not appropriate for modification in this study. However, metrics sensitive in the high biotic integrity range should be calibrated to detect disturbances. Of the eight metrics for which all sites scored perfect (total number of species, darter species, intolerant species, percent tolerant, percent insectivores, simple lithophils, percent DELT (deformity, erosion, lesion, tumor) anomalies, and number of individuals), only three are sensitive in the high biotic integrity range (Karr et al. 1986). Therefore the highly sensitive metrics (total number of species, darter species, and intolerant species) were altered for use in the Russell Fork drainage. Methodology used for adjustment of scoring criteria follows that outlined by KDOW (1997). Due to the moderate to low level of human impacts on the Russell Fork and high diversity encountered, it was determined that none of the collections should score one for any of the metrics being altered. Therefore, raw metric values for all sites were calculated and lines of demarcation were established that would divide the sites into two approximately equal groups scoring five and

Table 4. IBI Scoring criteria modified from KDOW (1997) for sites with ca. 600 mi^2 drainage area in Russell Fork, Pike County, Kentucky.

Metric	Scoring criteria 5	3	1
Total # of species[a]	>24	24–18	<18
# of darter species	>8	8–6	<6
# of sunfish species	>1	1	0
# of sucker species	>1	1	0
# of intolerant species[a]	>14	14–12	<12
% tolerant species	<30	30–60	>60
% omnivores	<20	20–50	>50
% insectivores	>55	25–55	<25
# top carnivore species	>1	1	0
# simple lithophils	>8	8–4	<4
% DELT anomalies	<0.1	0.1–1.3	>1.3
# of individuals	>100	50–100	<50

[a] Metric modified for this study.

three (Table 4). For total number of species, a score of three was given to sites with 18 to 24 species, and a score of five was given to sites with more than 24 species. For darter species, a score of three was given to sites with six to eight darter species, and a score of five was given to sites with more than eight darter species. For intolerant species, a score of three was given to sites with 12 to 14 intolerant species, and a score of five was given to sites with more than 14 intolerant species.

By use of the modified metrics, the mean score for all sites was 51.8 (good). Site three and a collection from site one had the highest scores, 58 (excellent), and site two had the lowest score, 40 (fair) (Table 5). These values are consistent with the quality of habitat found at each site and the overall biotic integrity of the Russell Fork. Site three had loose cobble substrate in a riffle ca. 30 m long lined with water-willow (*Justicia americana*). At site two, the substrate was much more embedded, and degradation of habitat due to the ongoing construction of a bridge was likely impacting the fish community.

To be complete, the modified metrics need to be based on more data, including data from sites with various sized drainage areas throughout the upper Big Sandy River system. However, based on disturbances observed in this study, it does appear that fish community response to disturbance is reflected in these metrics. While the metrics presented in this study are not intended to be a complete remedy to the problem of bioassessment in the upper Big Sandy, they appear to more accurately detect a decline in water quality than the WAE metrics.

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Table 5. Scores for sites in Russell Fork, Pike County, Kentucky sampled during 1998 using modified IBI metrics

Metric	Site 1[a]	1[a]	2	3	4	5	6	7	8
# species	5	5	3	5	3	3	3	5	3
Darter species	5	3	3	3	3	5	5	5	3
Sunfish species	3	5	1	5	1	3	1	3	3
Sucker species	5	5	1	5	5	5	3	5	5
# intolerant	5	3	3	5	3	5	3	3	3
% tolerant	5	5	5	5	5	5	5	5	5
% omnivores	5	5	3	5	5	3	5	3	5
% insectivores	5	5	5	5	5	5	5	5	5
# carnivores	5	5	1	5	3	5	1	5	5
# lithophils	5	5	5	5	5	5	5	5	5
% DELT	5	5	5	5	5	5	5	5	5
# individuals	5	5	5	5	5	5	5	5	5
Total	58	56	40	58	48	54	46	54	52
Overall mean = 51.8									

[a] Site sampled twice.

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Astrometric Measurements of the Pointing Accuracy of the Morehead Radio Telescope

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ABSTRACT

The Morehead Radio Telescope (MRT) is designed for investigations of the atomic hydrogen emission line at 1420 MHz associated with cosmic phenomena. The MRT supports undergraduate research in astrophysics, computer science, and pre-engineering at Morehead State University. The antenna system utilized is a Nike-Hercules 44-foot radar antenna that has been modified with azimuth-elevation drives and a phase-locked, low-noise receiver system. Pointing and tracking accuracies are essential to the performance of any telescope and to a great extent determine the science program of which the telescope is capable. To assure that the MRT is pointing precisely to the correct coordinates, a series of astrometric experiments was performed to calibrate the positioning system. By tracking the sun over the course of a day several times a year, a variety of coordinates could be observed ranging from ca. 20° to 80° in elevation and 75° to 270° in azimuth. The measured coordinates of the sun were those actually measured by the MRT during these experiments, these were compared to the expected coordinates supplied by the Astrometric Division of the United States Naval Observatory (USNO) for Morehead, Kentucky, and the errors were then computed. The data showed that the MRT, as expected, has positional errors. As the antenna is driven to an azimuth greater that 160° the error increases, as it does for elevations above 50°. We infer three primary causes for these errors: (1) The concrete foundation upon which the pedestal is mounted is not perfectly level, (2) The antenna pedestal is not orthogonal with respect to the local horizon and zenith, and (3) The antenna reflector is subject to gravitational deformations and the cosecant effect at high pointing elevations. To correct for these deficiencies, a data table will be constructed for every 0.10° in azimuth and elevation, which represents 10% of the antenna beam measured at the half power points. These correction factors will then be incorporated into the telescope pointing algorithms. Correcting for the MRT's pointing errors will greatly enhance telescope performance.

INTRODUCTION

The Morehead Radio Telescope (MRT), Morehead State University, Morehead, Kentucky, collects radiation from the electromagnetic spectrum at the hydrogen emission line corresponding to a frequency of 1420 MHz. For reliable observations the MRT pointing errors must be minimized. A primary function of the MRT is to map the distribution of atomic hydrogen associated with cosmic phenomena. Correlation of the atomic hydrogen distribution of an object with its optical counterpart provides significant insight into the nature of the phenomena. This correlation, however, requires pointing accuracies to angles significantly smaller than the antenna's beamsize (Kraus 1986).

A series of experiments was performed in which positional data of the sun was recorded every 5 min as the sun was tracked over the course of a day and at two different times during the year. The measured coordinates where then compared to the expected coordinates provided by the USNO. Taking the expected azimuth-elevation (USNO) and subtracting the measured (MRT) azimuth-elevation, we arrived at an error for each 5-min interval. The resulting data were graphed and compared to data taken on different days of observation. The errors show that the MRT has significant error in elevation, especially at elevations higher than 50°, and small errors in azimuths greater than 160°. The procedures followed during these observations are described in some detail in this paper.

INSTRUMENTATION AND METHODS

Drive Control

The positioning system of the MRT has been revamped many times, both in terms of controlling and feedback (position indicator) hardware and software that drives the antenna and automates the data collection (Malphrus 1998). However, the basic hardware has remained consistent with the original system (Kruth 1994). To monitor the elevation and azimuth of the antenna system a set of U.S. Digital A2 absolute encoders are used. An absolute encoder is a non-contacting optical rotary position sensor that gives shaft angles over 360°. An infrared LED flashes through a circular barcode onto a linear array sensor, then the microcontroller decodes the information on the barcode into an absolute position rather than a change in position. The encoder also contains an EEPROM (electrically erasable programmable read only memory device) that contains programmable parameters such as: resolution (0.1°), origin (0° equals due east), direction (counter clockwise), and mode (normal). The absolute encoder uses the SEI (Serial Encoder Interface) bus, which is a network of devices interfacing to a RS-232 serial port. The controlling computer uses the serial port to request the binary position data, which are then converted to a hexadecimal format by the software. The MRT uses two versions of the A2 absolute encoder, a shaft version that uses ball bearings to give position in azimuth and an inclinometer version that uses a gravity-referenced system to indicate position in elevation (USD 2002).

The shaft version of the A2 absolute encoder is attached to a drive shaft on the azimuth axis that is on a one-to-one ratio with the telescopes azimuth bull gear. As the telescope rotates, the optical disk in the absolute encoder rotates in tandem and thus gives an absolute position of the azimuth axis. The inclinometer version of the A2 absolute encoder has an optical disk that is counterweighted to keep the bar code stationary and allows the linear array sensor to move as the elevation increases or decreases. This action allows the elevation position be read into the serial port of the controlling computer.

Software Development

The software package, developed in-house by the Morehead State University undergraduate students and faculty, is utilized to position the telescope and collect data (including positional information in two coordinate systems and the radio frequency (RF) signal). The controlling software, currently Operator Program version 8.0, is continually updated to improve the MRT. The Operating Program, running on a dual Zeon Intel Processor controlling computer, interacts with the MRT receiver and control systems through a National Instruments Interface board. Operating Program 8.0 controls the positioning of the MRT in horizon coordinates (azimuth-elevation), tracks objects as the sky rotates over the course of the day, determines telescope position in azimuth-elevation via independent feedback loops, performs data storage and collection, and drives the telescope by communicating with translators that control DC drive motors for each axis. Operating Program 8.0 is written in LabView Virtual Instrumentation software in the graphical programming environment "G," that has accessibility to functions of the National Instruments P-6110 multi-function DAQ I/O interface card. "G" is ideal for the development of programs that require data collection and analysis as it facilitates communication with interface technologies. The absolute encoder of the positioning system interfaces through the SEI bus and the binary positional data is pulled into LabView where it is converted to a hexadecimal format. This allows routines within LabView to call hex numbers and translate them into a numerical angle that is displayed in the program. The software uses separate modules to call for the azimuth and elevation every 10 millisec. This allows the computer to precisely track on an object in the sky and give its coordinates in both the horizon system and equator system (right ascension (RA) and declination (Dec)).

Experimental Procedures

The sun was observed with the MRT total power receiver system, which operates at was 1420 MHz. Measured positions of sun were obtained from the ARTHEMIS Solar Archive web page, which calculates solar coordinates based on the user's latitude and longitude. The

Morehead Astrophysical Observatory is located at lat 38° 11′ 09″ N, long 83° 26′ 11″ W. A full daily solar ephemeris was obtained for our coordinates each day of the experiment. The solar ephemeris gives many useful daily measurements of the sun, but the one that is of concern to this project was equatorial coordinates of the sun for that day (ASA 2002). Once this information is received, the RA and Dec can be entered into the software allowing the computer to control the movement of the telescope. The computer will also track on this RA and Dec for the rest of the day. This makes matters extraordinarily easier for the observer. After the equatorial coordinates are entered into the software program and the telescope begins to move toward the position of the sun, the data from the USNO must be downloaded to the hard drive of the controlling computer and the expected azimuth and elevations of the sun can be entered into a spreadsheet. The USNO data have the calculated elevation and azimuth of the sun and the moon for many locations in the United States for each minute of the day. The position of the sun across the local sky is calculated for Morehead, Kentucky, and displayed; these data are utilized as the expected position of the sun for the MRT during the course of the day (USNO 2002). Then the computer clock time must be set for the experiment. To do this the Atomic Time Pro website is used. This website uses the atomic clock operated by the National Institute of Standards and Technology (NIST) in Boulder, Colorado as its timeserver. It then compares the atomic standard time to the time setting of the computer, and then allows the user to update the computer clock. Then the MRT's post-detection receiver gain must be set for the sun. Since the MRT is used to collect the emission of hydrogen from galactic and extragalactic objects, the gain can be set very high allowing the maximization of the deflection for weak or distant sources. The sun radiates strongly at 1420 MHz owing to its proximity, so the gain must be set low to scale down the incoming signal. Gains and offsets are set to maximize the deflection of the sun on the output scale. Then when the sun comes into the field of view of the MRT, the azimuth and elevation are peaked out in turn. Peaking out the signal gives the maximum amount of signal received from the sun, thus ensuring that the antenna beam is pointed precisely at the target. The peak numbers are then entered into a spreadsheet as the measured position of the sun and the given data from the USNO are entered as the expected data. This procedure is then repeated every 5 min, until the sun sets.

RESULTS

The experimental data shows that there is a significant error in the positioning systems of the MRT. Our experiments imply that both azimuth and elevation have errors in position, as seen in Figure 1. The errors in the azimuth and elevation positioning system were computed by taking the difference between the measured and expected values for the sun. A "zoomed in" version of the graph distinctly shows the difference in the expected and measured azimuth and elevations. At azimuths greater than 215° the error increases (when the telescope is pointing northwesterly) see Figure 2. As with azimuth, the error in elevations was computed and graphed. Figure 3 shows that the elevation error increases as the MRT's elevation rises above 50°. The error computed for the azimuth gives the most striking results, illustrating the "cosecant effect" caused by the inability of the telescope to unambiguously determine the telescope azimuth at high elevations. In Figures 4 and 5 the cosecant effect is seen between 1245 and 1415 and 1200 and 1445 respectively when the sun is moving slow in elevation. Also seen in both graphs is the gradual increase in the azimuth error just after the cosecant effect is observed at 1430. The errors computed for the elevation are also seen in Figure 4 and 5. These errors are high between 1245 and 1415 and 1200 and 1445 respectively. This error is evident as the telescope is pointing at its highest elevations of the day. Also seen is the gradual increase in error due to the cosecant effect, which continues until the sun is out of the view of the telescope. All the Figures 1 through 5 show that data taken months apart match up rather well.

DISCUSSION

Data shown in these graphs clearly establish the MRT's positioning errors and provide clues as to the underlying reasons for the errors. The cosecant effect illustrated earlier in

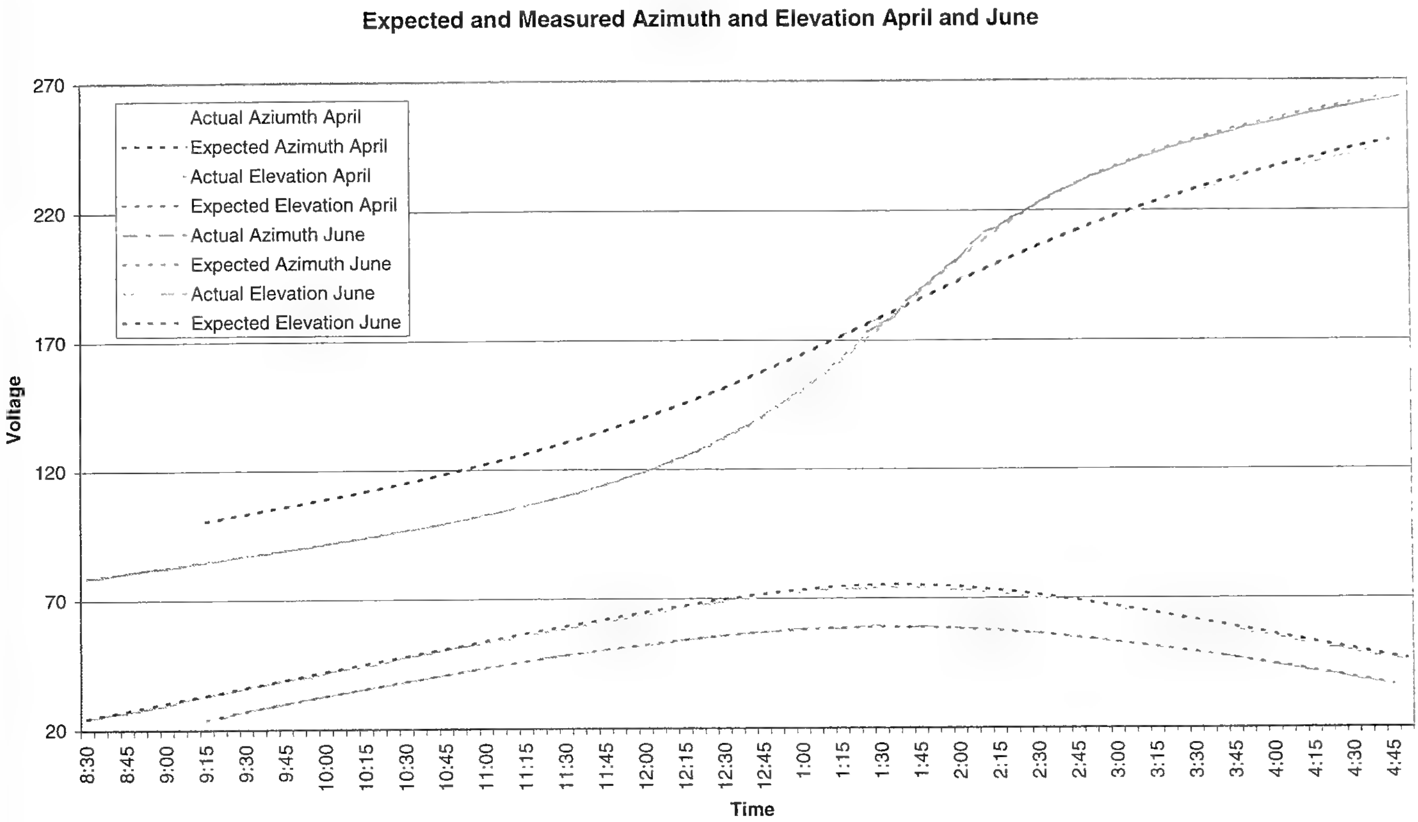

Figure 1. Morehead Radio Telescope, Morehead State University, Morehead, Kentucky. Comparison of the measured (MRT) and expected (USNO) azimuth and elevation of the sun on 7 Apr 2002 and 21 June 2002.

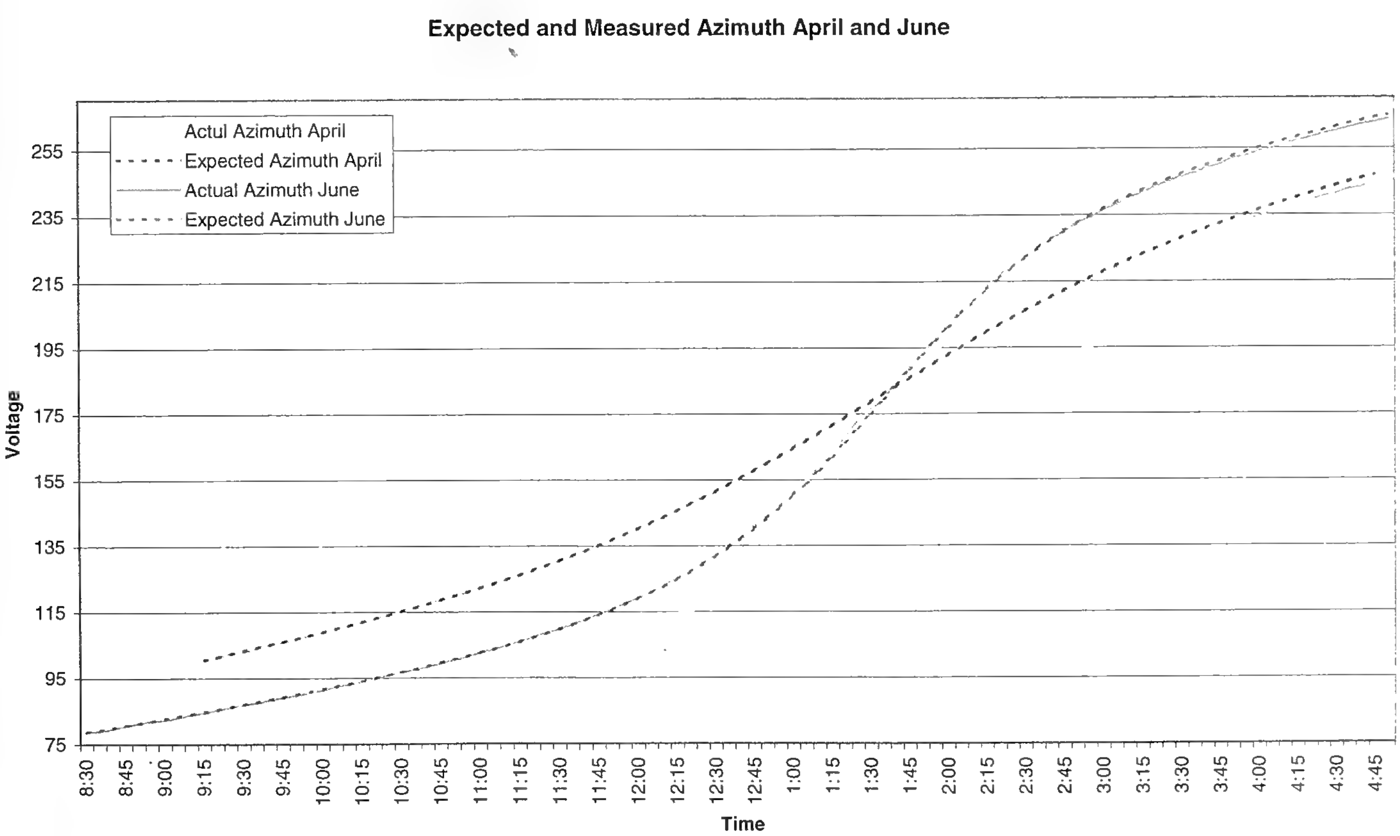

Figure 2. Morehead Radio Telescope, Morehead State University, Morehead, Kentucky. Measured and expected azimuth over the collection time on 7 Apr 2002 and 21 June 2002.

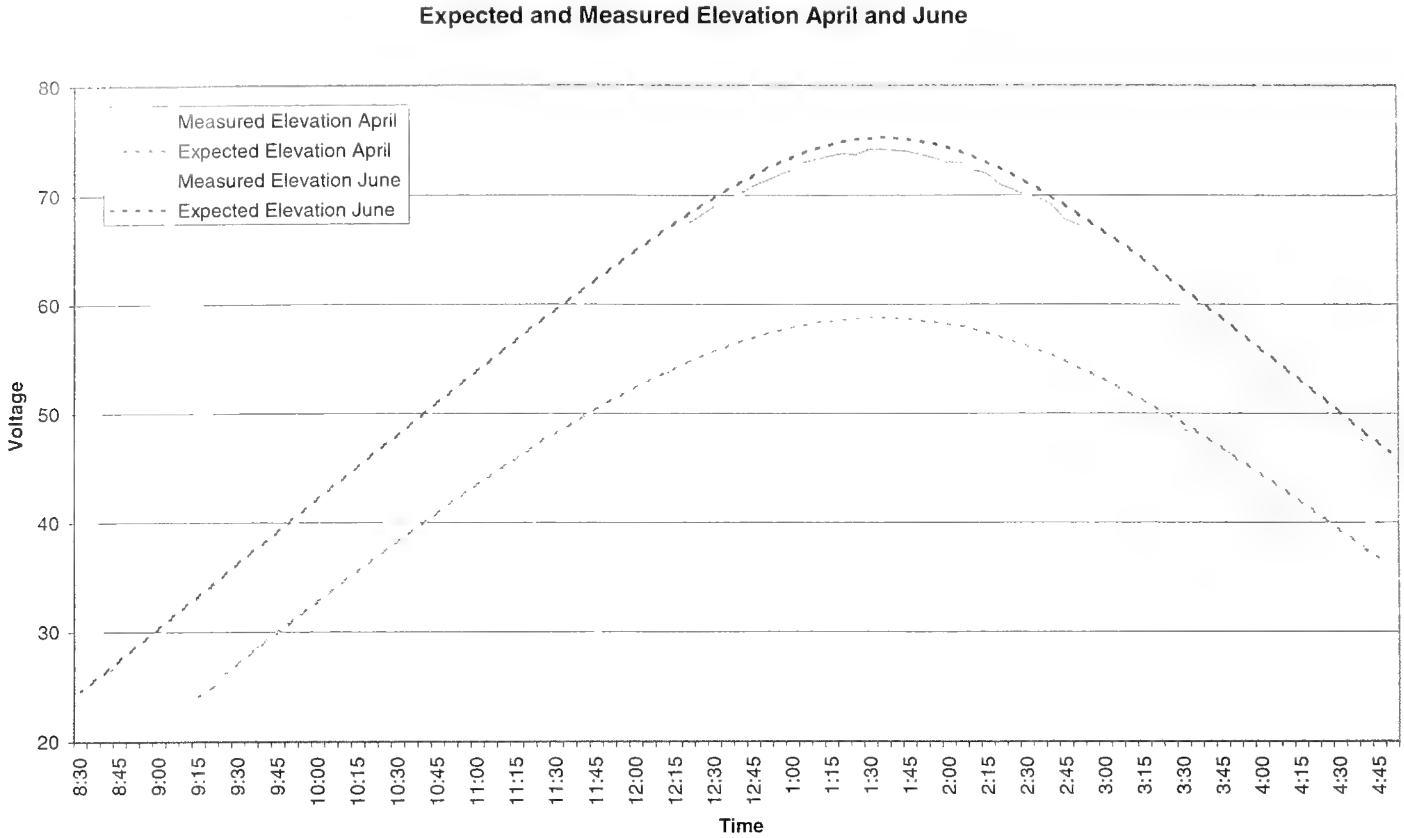

Figure 3. Morehead Radio Telescope, Morehead State University, Morehead, Kentucky. Measured and expected elevation over collection time on 7 Apr 2002 and 21 June 2002.

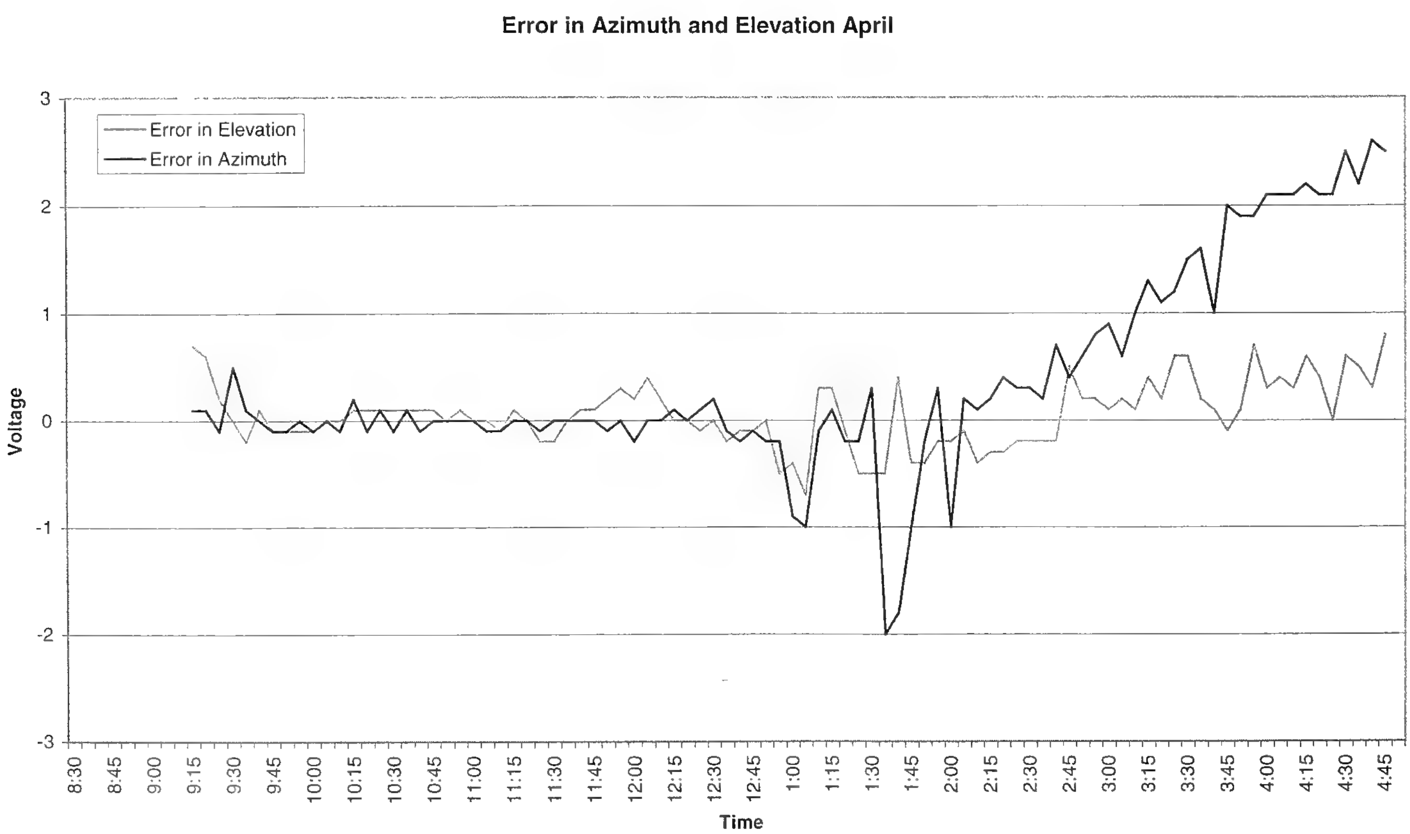

Figure 4. Morehead Radio Telescope, Morehead State University, Morehead, Kentucky. Error of azimuth and elevation as a function of time. These data were taken on 7 Apr 2002.

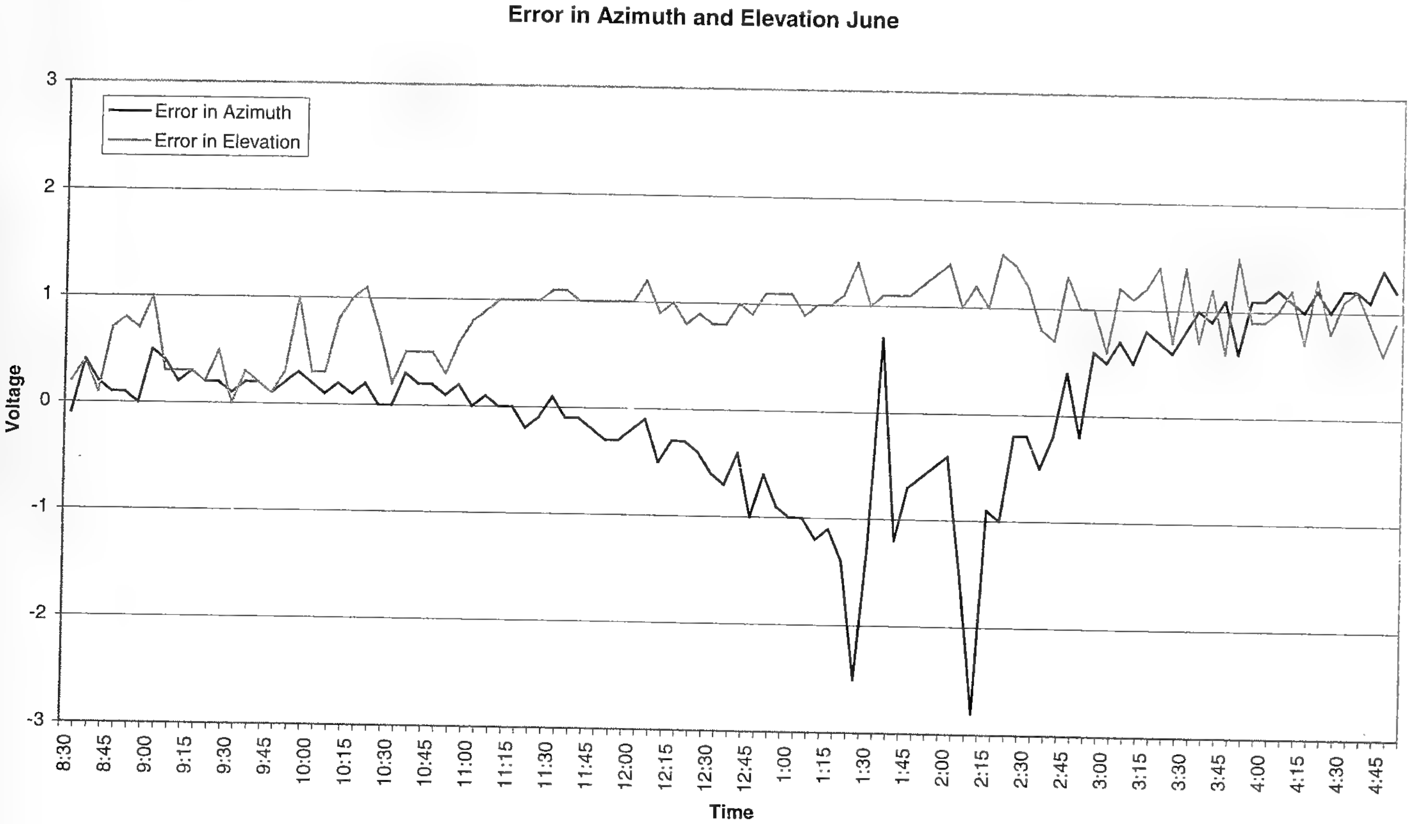

Figure 5. Morehead Radio Telescope, Morehead State University, Morehead, Kentucky. Error of azimuth and elevation as a function of time. These data were taken on 7 April 2002.

Figures 4 and 5 indicates that, as the sun reaches its maximum elevation, ambiguity related to its position in azimuth increases. Generally, this problem indicates that azimuth error increases as a function of elevation at high elevations. This "cosecant" effect is expected to a certain degree in all Alt-Az radio telescopes. Another effect seen was that the base is not level and not orthogonal. This is shown in Figures 4 and 5, as there is a distinct increase in error for azimuth above 215°, and in elevation after 1430 in Figure 4 and 1450 in Figure 5. Another reason for the elevation error at high elevations is a defocusing of the electrical focus, caused by a folding out of the outer areas of the telescope reflector, which is an effect of gravitational deformation.

The primary sources of error in this experiment were a result of human response and time lag associated with calibration of the time standard utilized. The average human response time to a visual stimulus is 384 millisec (Kosinski 2002). Because Atom Time Pro uses the atomic clock in Boulder, Colorado, 1268 miles from Morehead, Kentucky, it creates a time lag of ca. 116 millisec for travel through the Internet (AT 2002). This interval was measured by "pinging" the NIST server from the MRT controlling computer. The ping process measures the roundtrip time interval between the two computers by sending a number of packets back and forth and measuring the average time interval. These two effects are additive creating a total time lag of 500 millisec. This total time lag occurs for both azimuth and elevation. However, this time lag is much smaller than the error computed for the positioning systems. The smallest unit of time that the USNO uses in its computation of the sun and moon's respective azimuth and elevation is one min. This time lag of 500 millisec is much smaller. The average angle change for every min is 0.20°. The time lag of 0.500 sec (which translates to a maximum angle on the sky of 0.0020°), is much smaller than this value, and as the MRT's half power beamwidth is 0.911° by 3.6° (Malphrus 1999) the resulting error was imperceptible.

To correct the positioning system of the MRT, an error table will be established for every 0.1 degrees in azimuth and elevation. Then this table will be integrated into the software (as a library called by a higher-level operating algorithm) creating a corrected positioning system. This correction method will be

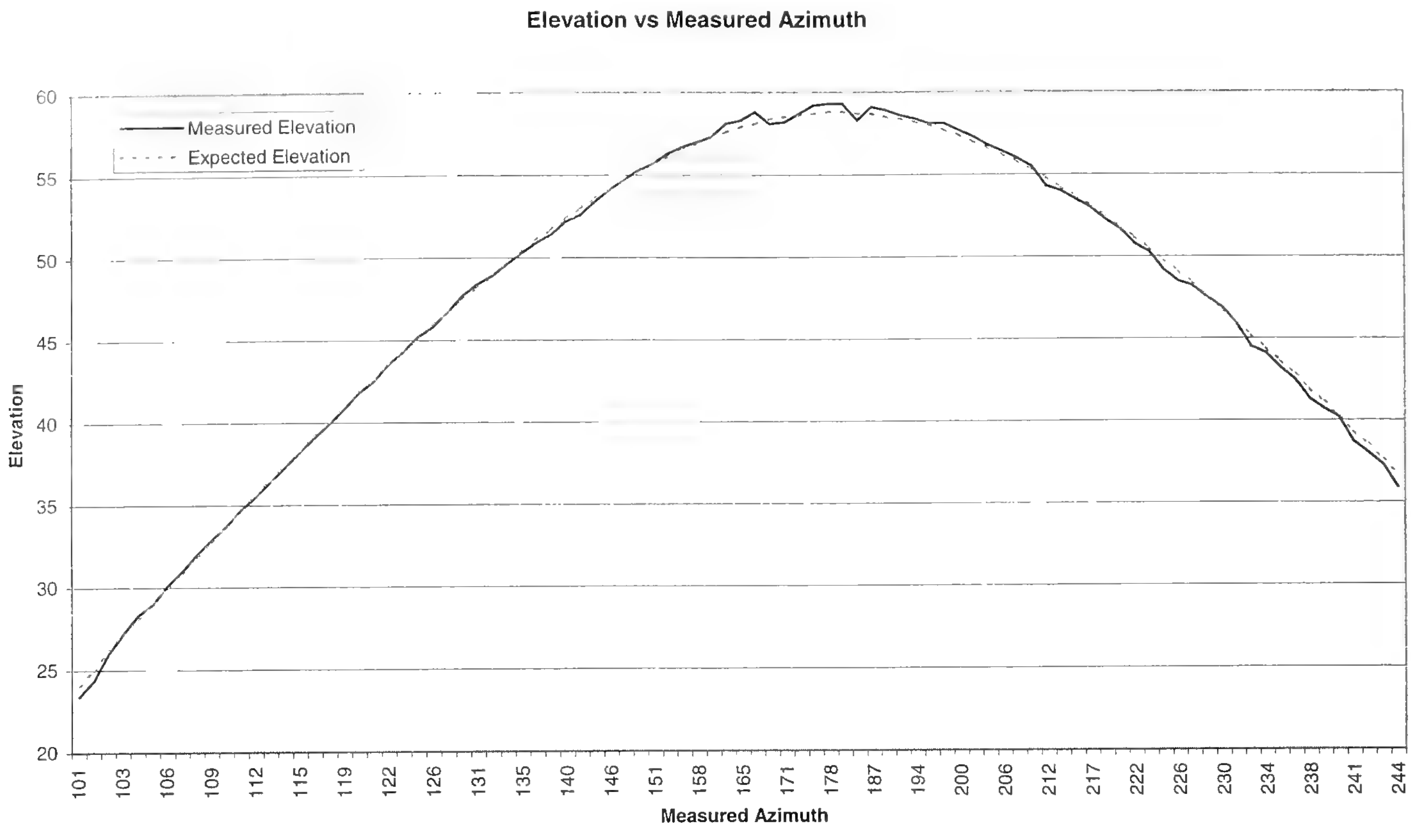

Figure 6. Morehead Radio Telescope, Morehead State University, Morehead, Kentucky. Predicted elevation and measured elevation as a function of azimuth, 7 Apr 2002.

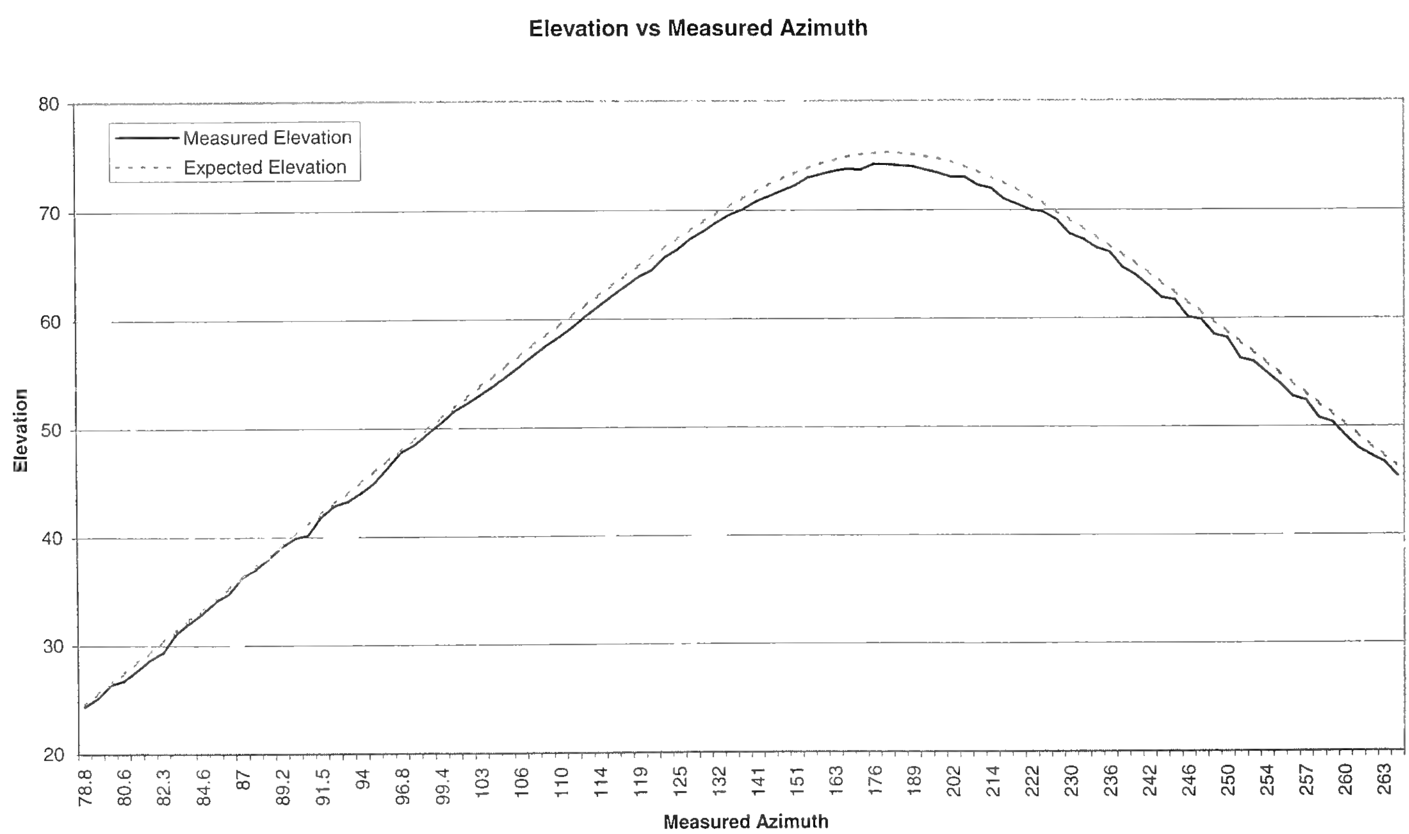

Figure 7. Morehead Radio Telescope, Morehead State University, Morehead, Kentucky. Predicted elevation and measured elevation as a function of azimuth, 21 June 2002.

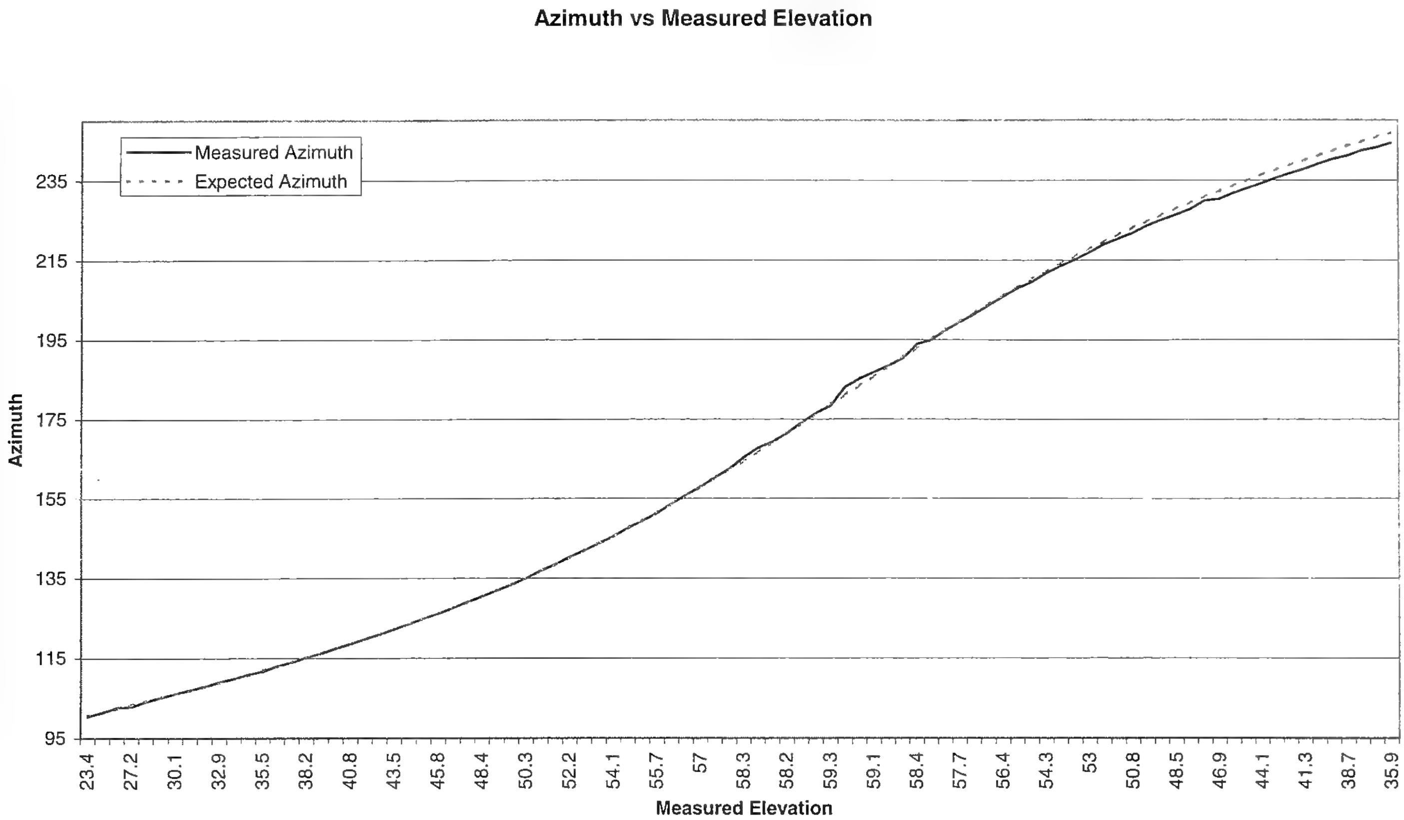

Figure 8. Morehead Radio Telescope, Morehead State University, Morehead, Kentucky. Predicted azimuth and measured azimuth as a function of elevation, 7 Apr 2002.

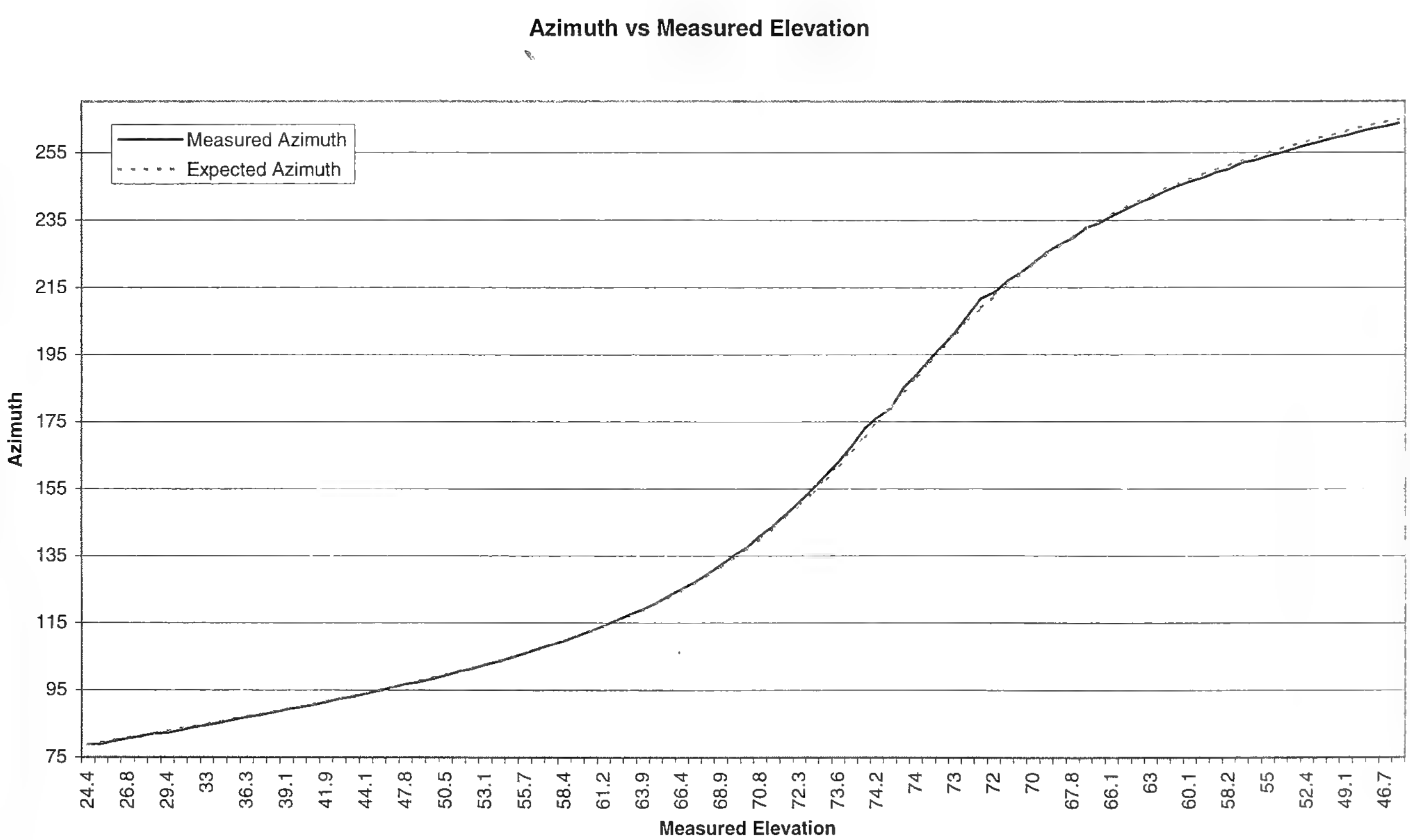

Figure 9. Morehead Radio Telescope, Morehead State University, Morehead, Kentucky. Predicted azimuth and expected azimuth as a function of elevation, 21 June 2002.

implemented and tested in a series of future experiments.

SUMMARY

To begin creating an error table, scans of the sun for this experiment were graphed as the measured and expected elevation verses the measured azimuth of the telescope, and the measured and expected azimuth verses the measured elevation. This then allows for a table to be generated for these particular equatorial coordinates. Data for these correction tables are plotted in four graphs shown below in Figures 6 through 9.

These experiments have shown that the MRT has pointing errors that are of some concern; however, development of the error table will solve this issue and allow for the telescope's controlling software to correct for these errors in position. This strategy represents an efficient and cost-effective solution to the problem, and a means to improve the accuracy of the MRT's positioning system.

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Demographic Influences on Peregrine Falcon Reintroduction in Kentucky

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ABSTRACT

As part of a project to restore the American peregrine falcon (*Falco peregrinus anatum*) in Kentucky cliff habitat, we initiated a series of pre-release evaluations designed to promote efficient allocation of project resources and to provide empirical support for decision-making. Pre-release evaluations included development of a demographic model examining the relative influence of first-year mortality, rate of philopatry, and founder cohort size on population persistence for 20 years. Using VORTEX, we simulated reintroductions in which 6–96 peregrine falcons were released annually for 3 consecutive years under conditions of first-year mortality and rate of philopatry that were 0.45–0.65 and 0.03–0.15, respectively. We used logistic regression to conduct sensitivity analysis. We compared standardized regression coefficients (b_n/SE_n) to quantify and rank the magnitude of effect on model outcomes at year 20 associated with changes in input parameter values. Founder cohort size accounted for the most variability ($b/SE = 9.85$) in the probability of persistence at year 20. First-year mortality and rate of philopatry affected the persistence of reintroduced peregrine falcon populations to a lesser extent ($b/SE = 4.86$ and -0.11, respectively). High first-year mortality (0.65) precluded population reestablishment regardless of founder cohort size. Similarly, releasing <48 peregrine falcons annually for 3 consecutive years resulted in high extinction probability (≥0.8) and low population size at year 20 (≤0.6), regardless of variation in first-year mortality and rate of philopatry. To address the influence of high first-year mortality on population recovery, we recommend a formal assessment of risk of predation or other sources of mortality at potential release sites. However, program financial resources should be allocated largely to maximizing founder cohort size because, given identification and avoidance of potential release habitats where first-year mortality likely would be high (i.e., ≥0.65), successful restoration of peregrine falcons in Kentucky cliff habitat will be predicated on maximizing the number of peregrine falcons released.

INTRODUCTION

In 1993, efforts were initiated to restore the peregrine falcon in Kentucky. As part of the project, 82 peregrine falcons were released during 1993–1999 at three urban or industrial locations in central Kentucky (i.e., one skyscraper and two coal-fired power plants). Although no peregrine falcons released at these locations are confirmed to occupy territories in the state, several Kentucky-released peregrine falcons occupy territories in the adjacent Ohio and Indiana (L. Burford pers. comm.). Similarly, peregrine falcons hacked or wild-produced in other regions of North America have established territories in Kentucky; four pairs of peregrine falcons occupy urban or industrial breeding locations in the Ohio River valley in northern portions of the state. In 1999 the American peregrine falcon was removed from the federal endangered species list (USFWS 1999). Unfortunately, historic habitats in Kentucky, including cliffs throughout the eastern portion of the state (Mengel 1939, 1965), remain unoccupied, and the peregrine falcon retains endangered status statewide. Recently, efforts to restore the peregrine falcon in Kentucky shifted to historic cliff habitats. For peregrine falcons, attributes of the natal site strongly influence choice of breeding site (Tordoff and Redig 1988; Tordoff et al. 1998), so efforts to reintroduce the peregrine falcon in Kentucky cliff habitat represent a distinct component of the program in terms of conservation and research objectives.

As a regional program, Kentucky cliff releases will be conducted without the broad logistical and financial support that characterized peregrine falcon management under the Endangered Species Act (Cade et al. 1996; Restani and Marzluff 2001). Accordingly, a key strategy in developing the program will be inclusion of protocols designed to promote efficient allocation of resources and management effort (see Bustamante 1996; Goodman 1980; Holroyd and Banasch 1990; Kleiman et al. 1991; Tordoff and Redig 1988). Initial considerations in implementing this strategy included identifying facets of the program that would be both amenable to management influence and that had implications for program resource allocation and success. For these considerations, we identified release site selection and determination of optimal founder cohort size as important because both facets yield various management options in their implementation and can incur logistical, financial, and demographic consequences that affect program success. For example, physiography, intensity of recreational use, and the abundance of prey, predators, and refugia at release sites can affect first-year mortality and influence the rate and scale of philopatry among reintroduced peregrine falcons (Barclay and Cade 1983; Black 1991; Hickey 1942; Hunt 1988; Sherrod 1983; Tordoff and Redig 1988). Similarly, founder cohort size, or the number of animals released, strongly influences the probability of successfully reestablishing peregrine falcons (Burnham et al. 1988; Grier and Barclay 1988; Griffith et al. 1989). A comprehensive assessment of Kentucky cliff habitat for release site suitability, while potentially advantageous in terms of reducing first-year mortality and promoting philopatry, would be cost prohibitive because cliff habitat is extensive and occurs throughout the state (e.g., Inner Bluegrass, Cumberland Plateau, and Cumberland Mountains). Likewise, the average cost of juvenile peregrine falcons suitable for hacking can exceed $1000 each.

Population viability analysis (PVA) is applied widely in conservation science as a quantitative tool to assess demographic factors that contribute to the decline or extinction of populations (e.g., Shaffer 1981; see Reed et al. 2002). Applications of PVA include modeling the effects of different management strategies (Plissner and Haig 2000), and evaluation of reintroduction options (Bustamante 1996; Green et al. 1996; South et al. 2000; Southgate and Possingham 1995). Our objective was to use PVA to quantify the relative magnitude of effect that potential demographic consequences of release site choice (i.e., rates of first-year mortality and philopatry) and founder cohort size have on restoring a breeding cohort of peregrine falcons. As proposed, the program included release of 12 peregrine falcons in Kentucky cliff habitats in each of 3 consecutive years.

MATERIALS AND METHODS

Input Parameters

We used VORTEX 8.21 (Miller and Lacy 1999) to construct metapopulation simulations of peregrine falcon reintroduction. We modeled population viability for 20 years (Beissinger and Westphal 1998; Tordoff et al. 2000). We derived demographic values from the peregrine falcon literature (Table 1). We simulated metapopulation structure under seven supplementation schedules characterized by the release of 6, 12, 24, 48, 60, 72, and 96 peregrine falcons, respectively, in each of 3 consecutive years (see Beissinger and Westphal 1998). We chose these supplementation schedules to reflect the proposed design of the program (e.g., release of 12 peregrine falcons per year for 3 consecutive years) and our capacity to manipulate founder cohort size (we chose multiples of six for potential interpretive purposes). We constructed 21 metapopulation models by combining low first-year mortality with a high rate of philopatry, median rates for first-year mortality and philopatry, and high first-year mortality with a low rate of philopatry in each of the seven respective supplementation schedules. We nullified implications of carrying capacity (K) by specifying K at 500 (Bustamante 1996). This enabled simulating release of large numbers of peregrine falcons without model truncation, as VORTEX eliminates individuals if K is exceeded. We estimated a density dependence function that emphasized Allee effects, such as decreased fecundity or survival because of low population numbers ($\beta = 4$, $A = 4$; Miller and Lacy 1999; Nelson 1988). We did not include inbreeding in our models because we will obtain young peregrine falcons from several unrelated sources. We did not include catastrophes (i.e., extreme environmental variation affecting reproduction and/or survival) in our models.

Metapopulation Structure

In raptors, non-breeding individuals, or floaters, can comprise a considerable portion of a population (Hunt 1998). Floaters have implications for modeling raptor reintroduction because they can augment reintroduced populations, mask population trends, or incur density dependent pressures (Hunt 1998). VORTEX enables modeling of metapopula-

Table 1. Parameters, initial estimates, and sources for demographic data used in simulating peregrine falcon reintroduction.

Parameter	Reintroduced	Floating (non-breeding)	Source
Type of mating system	Monogamous		
Age at first reproduction	2		Ratcliffe 1993; Tordoff and Redig 1997
Maximum breeding age	15		Tordoff et al. 2000
Sex ratio at birth	1:1		Ratcliffe 1993
Maximum brood size at fledging	4		Hickey 1942; Cade et al. 1988; Redig and Tordoff 1989; Steidl et al. 1991; Boynton and Currie 1993; Ratcliffe 1993
Density dependent fecundity?	Yes		Hunt 1988, 1998
Survival during migration[1]	26–45%		Barclay and Cade 1983; Burnham et al. 1988; Holroyd and Banasch 1990; Boynton and Currie 1993
Migration rate between populations[2]	95%	3–15%	Barclay and Cade 1983; Burnham et al. 1988; Holroyd and Banasch 1990; Boynton and Currie 1993
Adult females that produce young each year	65 ± 5.2%	0.0%	Grier and Barclay 1988
Females raising 0 fledgling		100%	
Females raising 1 fledgling	23%		Ratcliffe 1993
Females raising 2 fledglings	39%		Ratcliffe 1993
Females raising 3 fledglings	29%		Ratcliffe 1993
Females raising 4 fledglings	9%		Ratcliffe 1993
Juvenile (age 0–1) mortality	55–84 ± 3.8%	55–84 ± 3.8%	Enderson 1969; Lindberg 1977, Grier and Barclay 1988; Mearns and Newton 1984; Nelson 1988; Wooten and Bell 1992; Ratcliffe 1993; Tordoff and Redig 1997
Immature (age 1–2) and adult mortality	21 ± 8%	21 ± 8%	Enderson 1969; Enderson and Craig 1988; Newton and Mearns 1988; Olsen and Olsen 1988; Tordoff and Redig 1997
Initial population size	0	55	Hunt 1998
Carrying capacity	500	500	Bustamante 1996
Supplementation schedule[3]	6–96		

[1] Based on estimated first-year mortality.
[2] Based on estimated average return rates.
[3] We simulated reintroduction of 6, 12, 24, 48, 60, 72, nad 96 peregrine falcons in each of 3 consecutive years.

tion dynamics based on rates of dispersal and migration among metapopulations. To include floaters in the model, we considered floaters part of a metapopulation interacting with reintroduced cohorts via migration and dispersal. Reintroduced peregrine falcons exhibit a pattern of unoriented wandering, or floating, during their first year after dispersal from the natal area (Ratcliffe 1993). Often a small proportion of the reintroduced cohort returns to the release area to establish territories. Thus, we modeled the reintroduced-floater metapopulation based on the concept of temporal variance in peregrine falcon fitness, promoting the floater strategy for individuals < age two, and subsequent migration to breeding populations at age two at known or estimated rates (Table 1; Barclay and Cade 1983; Smith and Arcese 1989). For purposes of the simulations, we defined philopatry as migration from floating to breeding, or reintroduced, cohorts. We estimated extant floater population size based on the equation of Hunt (1998); $Y = (j + 1)C$, where, under conditions of population equilibrium, Y is the number of non-adults at fledging time, j is the estimated annual survival rate of juveniles, and C is the size of the annual cohort fledging within a given area. To calculate C, we identified all peregrine falcon breeding locations within 300 km of an estimate of the geographic center of the Cumberland Plateau in Kentucky. We used 300 km

Table 2. Population viability analysis of a reintroduced peregrine falcon population with effects of variation in founder cohort size, and low, median, and high values for rate of philopatry[a] and first-year mortality.[b]

Factor	Founder cohort size	High rate of mortality and low rate of philopatry ($\bar{x} \pm$ SE)	Median rates of mortality and philopatry ($\bar{x} \pm$ SE)	Low rate of mortality and high rate of philopatry ($\bar{x} \pm$ SE)
Probability of extinction at year 20	6	1.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0
	12	1.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0
	24	1.0 ± 0.0	1.0 ± 0.0	0.8 ± 0.1
	48	1.0 ± 0.0	0.7 ± 0.1	0.5 ± 0.2
	60	1.0 ± 0.0	0.4 ± 0.1	0.4 ± 0.1
	72	0.8 ± 0.1	0.5 ± 0.2	0.2 ± 0.1
	96	0.7 ± 0.1	0.2 ± 0.1	0.1 ± 0.1
Population size at year 20	6	0.0 ± 0.0	0.2 ± 0.1	0.3 ± 0.1
	12	0.2 ± 0.1	0.1 ± 0.1	0.2 ± 0.1
	24	0.1 ± 0.1	0.4 ± 0.2	0.6 ± 0.2
	48	0.5 ± 0.2	0.7 ± 0.3	1.8 ± 0.3
	60	0.3 ± 0.1	1.9 ± 0.4	2.4 ± 0.5
	72	0.9 ± 0.4	2.1 ± 0.5	3.2 ± 0.6
	96	0.9 ± 0.3	3.8 ± 0.7	4.4 ± 0.8

[a] Rate of migration from non-breedng floating population to reintroduced population was 0.03, 0.09, and 0.15 for low, median, and high classes, respectively.
[b] Rate of first-year mortality for floating and reintroduced populations was 0.25, 0.45, and 0.65 for low, median, and high classes, respectively.

in an effort to include peregrine falcon breeding locations in nearby states, but given the nomadic movement patterns of subadult peregrine falcons, this distance was arbitrary. We used the geographic center of Kentucky's Cumberland Plateau in deriving our estimate because hacking will occur in locations in eastern Kentucky. We identified 21 breeding locations within this distance (M. Dzialak, unpubl. data). Using j = 0.30 and a reproductive rate of two young fledged per pair annually (Table 1), we estimated floater cohort size at ca. 55 individuals. We began each simulation with a stable age distribution within the floater population; however, each simulation began with a reintroduced population of zero. We identified extinction (quasi-extinction) as a reintroduced population size at year 20 of <two individuals.

Sensitivity Analysis

We randomly generated 100 values for first-year mortality and rate of philopatry, bound by their respective ranges of variation as presented in the literature, and we randomly generated 100 values for founder cohort size bound by the seven supplementation schedules. Following Biessinger and Westphal (1998), Cross and Beissinger (2001), and McCarthy et al. (1995, 1996), we conducted 10 iterations of VORTEX for each parameter set to produce a data set of 1000 observations of ending population size classified as extinct or persisting at year 20. We assessed the relationship between independent variables and the logit of the probability of extinction, and found the relationship to be linear (Hosmer and Lemeshow 2000). We performed logistic regression on the data set of 1000 observations using SAS® (SAS Institute, Cary, North Carolina, U.S.A.). The binary dependent variable for logistic regression was extinction or persistence. We calculated standardized regression coefficients (b_n/SE_n) by dividing the regression coefficient b of variable n by its estimated standard error (Cross and Beissinger 2001). We compared standardized regression coefficients to quantify and rank the magnitude of effect on model outcomes associated with changes in input parameter values (Cross and Beissinger 2001; McCarthy et al. 1995, 1996).

RESULTS AND DISCUSSION

Mean population growth rate r for reintroduced peregrine falcons was negative under all reintroduction scenarios. The effects of founder cohort size and release site choice on extinction probability and population size at year 20 were not independent (Table 2). For example, when a median rate of first-year mortality was combined with a median rate of philopatry, and when low first-year mortality was combined with a high rate of philopatry, large annual founder cohorts (≥48) provided considerably lower extinction probability, and greater population size at year 20 than smaller annual founder cohorts (<48; Table 2). However, the combination of high first-year mortality and a low rate of philopatry nullified any advantage of large founder cohorts because extinction probability was high and population size was low at year 20, regardless of founder cohort size (Table 2). Similarly, when large annual founder cohorts (≥48) were released, reductions in mortality and increases in rate of philopatry reduced extinction probability and increased population size at year 20 (Table 2). However, releasing smaller annual cohorts (<48) rendered improved survival and philopatry from low to high rates inconsequential, because extinction probability remained high and population size remained below quasi-extinction threshold (Table 2). Based on logistic regression, the size of the reintroduced cohort accounted for the most variability in the probability of extinction at year 20 (b/SE = 9.85). Reintroduced cohort size had over twice the effect of first-year mortality in terms of population persistence (b/SE = 4.68). Rate of philopatry contributed little in accounting for variability in population persistence (b/SE = −0.11).

Reed et al. (1998, 2002) recommended that researchers discuss demographic model results in terms of uncertainty because a number of factors can render demographic estimates and management recommendations unreliable (e.g., White 2000). For example, in our study, the reintroduced-floater metapopulation behavior used in the model, including estimation of the rate of migration from reintroduced to floating cohorts and of initial floater population size, involved some conjecture and represented considerable simplification of raptor ecology (Newton 1979). Spatial and temporal attributes of the flow of immigrants between populations are important aspects of metapopulation behavior (Gilpin 1987). Uncertainty in these estimates has implications for the reliability of demographic inferences based on the model. Similarly, the assumption of a general association between attributes of release sites and mortality and philopatry, while reasonable (Barclay and Cade 1983; Holroyd and Banasch 1990; Tordoff and Redig 1988), is a simplification of peregrine falcon ecology. Moreover, implicit in this study was the assumption that biologists in Kentucky can discriminate between low- and high-quality release sites accurately. Nonetheless, the demographic data upon which this study was based are extensive and reliable; model inferences invariably reflect the data upon which they are based. Further, using logistic regression to assess parameter sensitivity may enable more reliable inferences compared to conventional sensitivity analyses because the standardized regression coefficients are scaled by an estimate of variability or uncertainty (SE).

Reporting use of VORTEX to model reintroduction and viability of cliff-nesting raptor populations, Bustamante (1996) considered VORTEX able to simulate realistically most management options associated with reintroducing bearded vultures (*Gypaetus barbatus*) in cliff habitat. However, the ability of VORTEX to account for long-term monogamy typical of many raptor species and its genetic implications was questionable. Although we did not examine inbreeding in the model, it should be noted that VORTEX likely overestimates the extent of genetic interchange among monogamous raptors, and thus underestimates the extent of inbreeding (Bustamante 1996).

A negative mean growth rate of reintroduced peregrine falcon cohorts that characterized all simulations was expected based on the specified metapopulation dynamics. These specifications, including dispersal of reintroduced peregrine falcons and comparatively low rates of migration from floating to reintroduced cohorts, simulated some of the challenges associated with hacking peregrine falcons in unoccupied habitats. Upon dispersal, peregrine falcons can exhibit nomadic behavior for several years. Territorial establishment by floating individuals in suitable, but unoccupied cliff habitat is uncommon because floaters often are attracted more to conspecifics than to unoccupied habitats (see Tordoff et al. 1999, 2000, 2001). In our study, release site choice, modeled as first-year mortality and rate of philopatry, and founder cohort size interacted to influence population persistence. First-year mortality, rather than philopatry, was the more influential aspect of release site choice. Among demographic parameters, the rate of adult mortality most influences extant raptor populations (Grier 1980a; Hiraldo et al. 1996; Newton 1979; Wooten and Bell 1992), so it would be expected that first year mortality rates are similarly influential among reintroduced cohorts comprised entirely of juveniles. Philopatry influenced population persistence minimally likely because, as modeled, philopatry was governed by both mortality and founder cohort size. Generally, this study demonstrated that (1) in conditions of high first-year mortality (i.e., ≥0.65), recruitment of individuals into the breeding class was insufficient to enable population persistence for 20 years, and (2) given avoidance of high first-year mortality, the number of peregrine falcons released influenced population reestablishment to a greater extent than potential demographic consequences of release site choice. Moreover, when first-year mortality was <0.65, founder cohort size governed the practical utility of efforts to identify high-quality release habitats. For example, we found that releasing <48 peregrine falcons annually for 3 consecutive years rendered the demographic consequences of release site choice inconsequential because the probability of extinction was ≥0.8 and the population size at year 20 was ≤0.6 individuals, regardless of mortality and philopatry rates. Griffith et al. (1989) identified a direct relationship between founder population size and the probability of reintroduction success. In avian reintroduction, Griffith et al. (1989) demonstrated that increases in the probability of success were associated with releasing large numbers of individuals, and this association became asymptotic only after releasing ca. 100 individuals. We did not evaluate this relationship quantitatively, but our results suggested that for peregrine falcons, a greater number of individuals must be released to arrive at such an asymptote. Barclay and Cade (1983), Grier (1980b), and Grier and Barclay (1988) developed stochastic models that predicted the outcome of peregrine falcon reintroductions in the eastern United States. Using data encompassing the variability observed in extant populations, their model indicated that the probability of persistence was highest when the reintroduced cohorts exceeded 100 individuals. Field data also demonstrated the importance of founder population size in peregrine falcon reintroduction. For example, regionally, (e.g., Southern Appalachia and eastern Canada), successful reestablishment of peregrine falcons populations has been associated with release of ≥349 peregrine falcons over a period of ≥5 years (Boynton and Currie 1993; Holroyd and Banasch 1990).

Recommendations

Project resource allocation should be skewed heavily to maximizing founder cohort size. Successful restoration of peregrine falcons in Kentucky cliff habitat is predicated on releasing a large number of individuals (Barclay and Cade 1983; Burnham et al. 1988; Grier and Barclay 1988). This does not imply abandonment of efforts to identify suitable release sites. Clearly, peregrine falcons must be released in habitats in which the probability of excessive first-year mortality has been determined to be low. To identify release sites, we recommend a strategy combining a priori knowledge of peregrine falcon habitat associations and formal surveys estimating risk of predation or other sources of mortality. For example, abundance of great horned owls or other known predators of hacked peregrine falcons, such as red-tailed hawks (*Buteo jamaicensis*), should be estimated at potential release sites. Given the comparably short period of supplementation that characterizes the program, release of ca. 50 peregrine falcons in each of 3 consecutive years would be a preferred strategy. An alternate strategy would be to extend the duration of supplementation because duration often governs the feasibility of releasing large numbers of peregrine falcons. For example, releasing 20–22 falcons during the course of 7 years may be more feasible logistically than releasing larger cohorts over a shorter period.

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American Mistletoe (*Phoradendron leucarpum*, Viscaceae) in Rockcastle County, Kentucky

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ABSTRACT

American mistletoe (*Phoradendron leucarpum*), an obligate hemiparasitic shrub of certain eastern deciduous forest trees, was found on 3502 trees from 15 host species in 10 families in Rockcastle County, within the south-central region of eastern Kentucky. Black walnut (*Juglans nigra*), the preeminent of these host species, was most frequent in the Eastern Knobs and Eastern Highland Rim regions followed by wild black cherry (*Prunus serotina*). Blackgum (*Nyssa sylvatica*) was the most prevalent host tree in the Northern Cumberland Plateau. Post oak (*Quercus stellata*) and red elm (*Ulmus rubra*) were new host tree species documented for Kentucky. An aggregated or clumped spatial distribution pattern exists between American mistletoe and its host trees. The occurrence value was 4.35 infested trees per kilometer.

INTRODUCTION

American mistletoe, *Phoradendron leucarpum* (Raf.) Reveal & M. C. Johnston, is a shrubby evergreen hemiparasite on several deciduous trees within the Eastern Deciduous Forest of the eastern United States. The geographical distribution of the species is bounded by eastern Texas, southeastern Oklahoma, southern Missouri, Illinois, Indiana, and Ohio, southeastern Pennsylvania, and southern New Jersey southward to Florida and westward through the Gulf States (Scharpf and Hawksworth 1974; Wiens 1964).

American mistletoe is referred to as *P. flavescens* (Pursh) Nuttall or *P. serotinum* (Raf.) M. C. Johnston in most state floras and manuals of the eastern United States. Reveal and Johnston (1989) showed the correct nomenclatural combination to be *P. leucarpum* (Raf.) M. C. Johnston. Based on morphology, embryology, and cytology (Cronquist 1981; Kuijt 1982), *Phoradendron,* the New World mistletoes, are now classified in the Viscaceae, the Christmas mistletoe family, rather than in the Loranthaceae. The chromosome number of *P. leucarpum* is 2n = 28 (Baldwin and Speece 1957; Wiens and Barlow 1971).

This dioecious woody plant is characterized by opposite, glabrous, elliptic to obovate, coriaceous leaves. The inflorescence consists of short axillary spikes of inconspicuous, greenish white staminate or pistillate flowers. The fruits are white to whitish yellow, subglobose drupelike berries with a viscin layer within the pericarp and one or two chlorophyllous seeds (Kuijt 1969, 1982). *Phoradendron leucarpum* has long been considered an obligate hemiparasite that obtains water and inorganic minerals from the woody host (Hull and Leonard 1964a) but producing its own photosynthate by chlorophylls (Freeland 1943; Hull and Leonard 1964b).

Fruit and seed dispersal mechanisms of *P. leucarpum* primarily include ornithophily, or avian vectors, and to a much lesser degree by arboreal mammals and gravity (Bray 1910; Martin et al. 1951; York 1909). After fruit dispersal, the viscid pericarp layer of the berry adheres to a woody host branch where germination occurs. The hypocotyl-primary radicle forms a disclike holdfast through which endophytic haustoria penetrate the bark, vascular cambium, and xylem to absorb water and minerals. New growth then can occur with eruptions of shoots through the bark from lateral cortical strands on the long axis of branches. A leafy shoot forms within the first 2 years and a mature American mistletoe plant can develop flowers within 3 to 5 years (Calvin 1967; Kuijt 1982; York 1909).

Several host specificity studies were conducted during 1976–1989 in Georgia (Cole and Hemmerly 1981), Mississippi (Eleuterius 1976), Ohio (Spooner 1983), and Tennessee by Thomas E. Hemmerly, Middle Tennessee State University, and his students (Anderson and Mundy 1980; Brown and Hemmerly 1979; Ferguson and Hemmerly 1976; Hemmerly 1981; Hemmerly et al. 1979; Hemmerly et al. 1987; Henderson and Pekala 1980; McKinney and Hemmerly 1977; Rucker and Hemmerly 1976; Sadler and Hemmerly 1984). The present study of Rockcastle County is the first mistletoe survey for an entire Kentucky county. The only report of American mistletoe for Rockcastle County was a sight record by Braun (1943). Only two previous mistletoe studies have been published in Kentucky (Reed and Reed 1951; Thompson 1992). Our objectives were to identify American mistletoe-infested trees, inventory them by physiographic province, determine relative abundance and spatial distribution patterns, and record bird species perched in mistletoe-infested trees.

THE STUDY AREA

Rockcastle County is in south-central southeastern Kentucky and consists of 80,552 ha (199,040 acres) with ca. 52,206 ha (129,000 acres) forested (Ross et al. 1981). The population of Rockcastle County was 16,600 in 2000. The largest town and county seat, Mount Vernon, had a population of 3300 (U.S. Census Bureau 2000).

The continental temperate climate of Rockcastle County typically exhibits warm humid summers followed by moderately cold winters. Mean annual precipitation is 118 cm (46.6 in). Mean annual temperature is 12.7°C (54.8°F). Mean growing season is 181 days with the first killing freeze in mid-October and the last killing freeze in mid-to-late April (Ross et al. 1981).

Three major physiographic regions present in Rockcastle County are the Eastern Knobs (Knobs), Eastern Highland Rim (EHR), and the Northern Cumberland Plateau (NCP) based on Smalley (1986). The Eastern Knobs (15,385 ha) lie in the extreme north-northwestern portions of Rockcastle County; the Eastern Highland Rim (27,090 ha) lies in the southwestern-central portions; and the Northern Cumberland Plateau (38,077 ha) is located in eastern and southern Rockcastle County (Figure 1). The NCP forms part of the western region of the Appalachian Plateaus Province of Fenneman (1938).

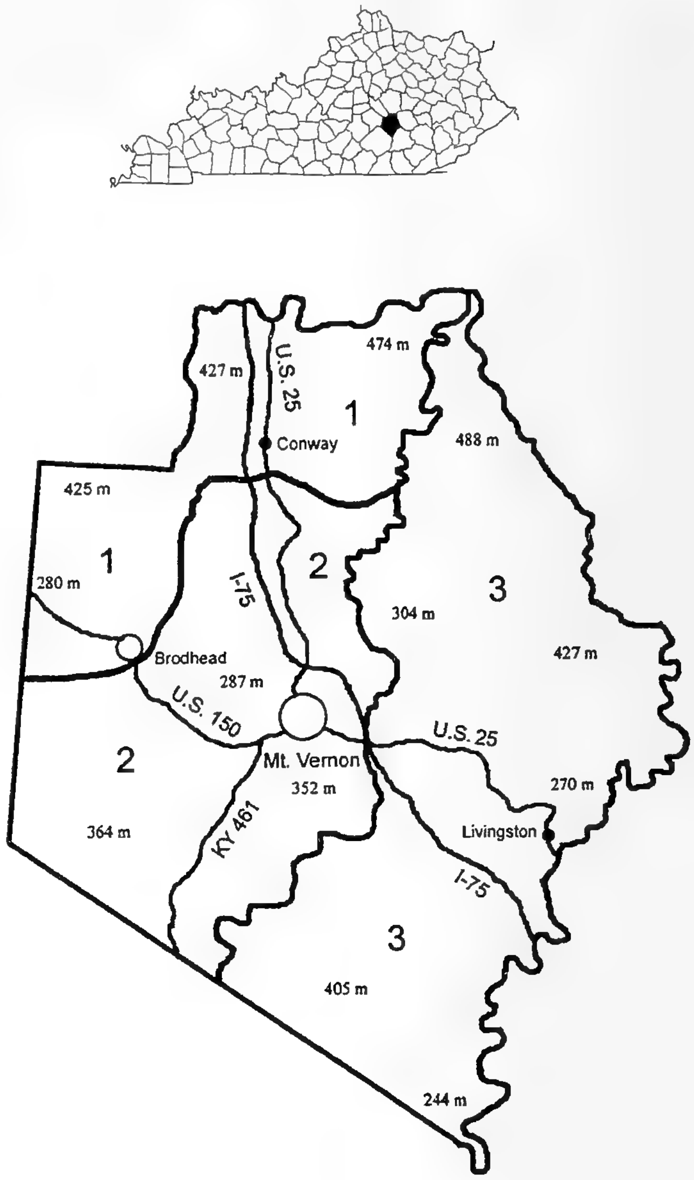

Figure 1. Rockcastle County, Kentucky, Physiographic Regions: (1) Eastern Knobs, (2) Eastern Highland Rim, (3) Northern Cumberland Plateau (Smalley 1986). Adapted from General Highway Map, Rockcastle County, Kentucky (Kentucky Department of Transportation 1991) and geologic map of Kentucky (McDowell et al. 1981).

In Rockcastle County, the Eastern Knobs are composed of Devonian and Mississippian shales, sandstones, siltstones, and dolomitic limestones. The terrain consist of moderately sloping conical rounded hills and ridges with U-shaped valleys drained by small streams. The EHR is composed principally of Mississippian limestones with some siltstones and shales, which results in a undulating dissected plateau with moderate side slopes and deep valleys along natural drainages. The NCP is composed mainly of Pennsylvanian sandstones, siltstones, conglomerates, and some coal. The elevated landforms have very rugged and steep side slopes, narrow ridges, and V-shaped valleys (McDowell et al. 1981). The highest point in Rockcastle County is near the Rockcastle/Madison County boundary at 488 m (1600 ft); the lowest elevation, 244 m (800 ft), is at the junction of the Rockcastle River contiguous to Laurel County (Ross et al. 1981).

Braun (1950) classified the vegetation of the Eastern Knobs as part of the Mixed Mesophytic Forest and Western Mesophytic Forest regions with mixed oak-hickory-pine at upper elevations and mesic hardwood forests at lower elevations. The Eastern Highland Rim lies within the Western Mesophytic Forest Region with oak-hickory and mixed mesophytic hardwood forests surrounded by agricultural lands. The Northern Cumberland Plateau is occupied by the Mixed Mesophytic Forest Region of predominantly mixed oak-hardwoods-pine forest. Küchler (1964) classified the potential vegetation of the Mississippian Plateau (Eastern Highland Rim) as oak-hickory forest and the vegetation of the Cumberland Plateau as mixed mesophytic forest (maple-buckeye-beech-tuliptree-oak-basswood).

MATERIALS AND METHODS

Field methodology for our mistletoe survey was adapted from Hemmerly (1989). During December 1991–January 1992, we traversed the paved and passable gravel roads within the boundaries of Rockcastle County with a four-wheel-drive vehicle. We used a 1991 Rockcastle County highway map divided into three physiographic regions to designate roads travelled and to document infested trees. We spotted trees with mistletoe from the vehicle while driving slowly using binoculars when needed. After a host tree was sighted, we stopped, investigated, and recorded data. Additional stops in favorable terrain resulted in a more through tabulation of isolated and heavily infested trees. All trees encountered with visible signs of American mistletoe infection (i.e., branch clumps or clusters, cankers, swellings, limb die-back) were identified, counted, and recorded by physiographic region. We tallied road mileage with the vehicle odometer and eventually totaled all the sums together to obtain an occurrence factor value. An occurrence factor is the density value of infested trees per kilometer and it is determined by dividing the total number of infested trees by the total kilometers travelled (Hemmerly 1989; Hemmerly et al. 1987; Sadler and Hemmerly 1984). This density factor represents both spatial distribution and relative abundance of host trees (Hemmerly 1989).

We collected representative American mistletoe and winter twig vouchers for certain host species and deposited them in the Berea College Herbarium (BEREA) and Eastern Kentucky University Herbarium (EKY). We obtained most of these specimens from host trees with a 12 m (40 foot) extendable fiberglass linesman pole and used a 12-gauge shotgun to secure certain specimens beyond the reach of the linesman pole. Nomenclature for trees species follows Gleason and Cronquist (1991).

RESULTS AND DISCUSSION

Host Occurrence of Mistletoe-infested Trees

Over 805 km (500 miles) of surface roads in one direction were traversed within the boundaries of Rockcastle County. A total of 3502 host trees from 15 species in 10 families were found to be parasitized by *P. leucarpum* (Table 1). Mount Vernon, centrally located in Rockcastle County within the Eastern Highland Rim, had 455 mistletoe-infested trees from 11 host species. The number of mistletoe-infested trees per road kilometer was 4.35. The occurrence value in Rockcastle County was considerably higher than those reported for counties surveyed in Georgia (Cole and Hemmerly (1981) and in Tennessee (Anderson and Mundy 1980; Hemmerly et al. 1987; Henderson and Pekala 1980; Sadler and Hemmerly 1984).

Three host trees—black walnut (*Juglans nigra* L.), wild black cherry (*Prunus serotina* Ehrh.), and blackgum (*Nyssa sylvatica* Marsh.)—accounted for 2764 trees of the 3502 total (Table 1). Post oak (*Quercus stellata* Wangenh.) and red elm (*Ulmus rubra* Muhl.) were documented as a new host tree species for Kentucky based on Reed and Reed (1951). Shagbark hickory [*Carya ovata* (Mill.) K. Koch] and sugar maple (*Acer saccharum*

Table 1. Host occurrence of *Phoradendron leucarpum* in Rockcastle County, Kentucky. Physiographic Regions (Smalley 1986): Knobs = Eastern Knobs; EHR = Eastern Highland Rim; NCP = Northern Cumberland Plateau.

Tree species	Knobs	EHR	NCP	Total	Percentage
Juglans nigra	571	1102	23	1701	48.57
Prunus serotina	112	513	11	636	18.16
Nyssa sylvatica	10	20	397	427	12.19
Fraxinus americana	14	187	22	223	6.37
Robinia pseudoacacia	37	109	15	161	4.60
Acer saccharum	31	90	24	145	4.14
Ulmus americana	10	89	8	107	3.05
Ulmus rubra	5	9	27	41	1.17
Acer saccharinum	0	23	0	23	0.66
Carya ovata	4	14	0	18	0.51
Gleditsia triacanthos	2	13	0	15	0.43
Celtis occidentalis	0	2	0	2	0.06
Diospyros virginiana	0	1	0	1	0.03
Maclura pomifera	0	1	0	1	0.03
Quercus stellata	0	1	0	1	0.03
Total: 15	796	2179	527	3502	100.00
Tree Percent by Regions:	22.73	62.22	15.05	100.00	

Marsh.) were reported for the second time; they were Kentucky distributional records not indicated by Thompson (1992).

The most host trees were located within the Eastern Highland Rim (2179) followed by the Knobs (796) and the Northern Cumberland Plateau (527). Black walnut was found to be the preeminent host species of the Eastern Knobs followed by wild black cherry, black locust (*Robinia pseudoacacia* L.), and sugar maple (Table 1). In the EHR, all 15 host species were found with black walnut accounting for 1102 trees. Wild black cherry, white ash (*Fraxinus americana* L.), black locust, sugar maple, and American elm followed in occurrence. Other mistletoe-infested trees were silver maple (*Acer saccharinum* L.), shagbark hickory, honey locust (*Gleditsia triacanthos* L.), red elm, common hackberry (*Celtis occidentalis* L.), Osage-orange [*Maclura pomifera* (Raf.) Schneid.], common persimmon (*Diospyros virginiana* L.) and post oak (Table 1).

Calcicolous host-tree species—wild black cherry, black walnut, American elm, white ash, black locust, sugar maple, and shagbark hickory—were most important in a mistletoe survey from the Lexington-Blue Grass Army Depot (LBAD) in Madison County, the northern contiguous county to Rockcastle County. The LBAD is located in the Outer Bluegrass Physiographic Region where the bedrock is composed largely of Ordovician limestones and dolomitic limestones (Thompson 1992). In fact, 11 out of 15 host tree species present in the EHR were found in the LBAD by Thompson (1992).

The Northern Cumberland Plateau had only eight host tree species present although it is the largest physiographic region in Rockcastle County. The principal host tree in the NCP was the acidophilic blackgum, which accounted for 397 trees in the survey. Occasional red elm, sugar maple, white ash, and black walnut also were present. Hemmerly et al. (1979) documented blackgum as the predominant host tree in Lawrence County, Tennessee. Reed and Reed (1951) listed blackgum as the most important mistletoe host tree for the Cumberland Plateau of Kentucky.

Avian Species Observed

Frequent overwintering birds perched in mistletoe-infested trees during this survey were the European starling (*Sturnus vulgaris*), red-winged blackbird (*Agelaius phoeniceus*), brown-headed cowbird (*Molothrus ater*), common grackle (*Quiscalus quiscula*) and American crow (*Corvus brachyrhynchos*). Infrequent non-migratory birds observed in trees with mistletoe included blue jay (*Cyanocitta cristata*), American robin (*Turdus migratorius*), cedar waxwing (*Bombycilla cedrorum*), northern cardinal (*Cardinalis cardinalis*), northern mockingbird (*Mimus polyglottos*), mourning dove (*Zenaida macroura*), and eastern bluebird (*Sialia sialis*). These 12 bird species have been reported as vectors of *Phoradendron* spp. in the combined studies of Bray (1910), Martin et al. (1951), and York (1909). Birds spread the infestation by ingesting the berries, defecating, and bill-wiping on bark and knocking fruits off onto the branches. The availability of avian vectors is another variable in the amount of tree infestation.

Analysis of Infested Trees

Mistletoe-infestation was observed in certain host tree species much more than others, and the degree of infestation was different among trees of the same species in a particular region and in contiguous physiographic regions. One factor in the amount of mistletoe infestation is correlated with the age and size of the host trees. Birds prefer to perch and feed in the upper crowns of older, larger, and taller mature trees. Other studies in *Phoradendron* spp. have made similar observations regarding host tree size (Hreha and Thomson and Mahall 1983; Weber 1979).

The amount of canopy closure in conjunction with available sunlight is also related to the incidence and degree of mistletoe infestation. In southern Mississippi, greater mistletoe infestation and mortality were observed in water oak (*Quercus nigra* L.) in open canopies than in closed canopies (Eleuterius 1976). More exposure to sunlight is beneficial for mistletoe photosynthesis, and light has also been observed to promote the germination of American mistletoe seeds (Gardner 1921).

Trees with open canopies of upland road corridors, forest edges, pastures, fields, yards, fencerows, and ridgetops of the Knobs and Eastern Highland Rim had a much higher incidence of infestation than host trees in closed forests of lower and upper slopes and forested riparian valleys of the Northern Cumberland Plateau. The prevalence of mistletoe in Mount Vernon was partly because available host trees and bird perching sites were available; we found that cities and towns typically provide host trees for infestation.

Another factor directly contributing to American mistletoe infestation is the increased availability of host trees along these open, upland habitats. More host trees for American mistletoe infestation were present in the EHR and Knobs than in the larger NCP. In Rockcastle County, the most severe infestations, which caused actual tree mortality in some cases, were most often observed in black walnut, wild black cherry, blackgum, and American elm.

The spatial distribution and dispersion of American mistletoe exhibits an aggregated (clumped) pattern (Barbour et al. 1999) or clustered distribution (Daubenmire 1968). American mistletoe surveys in Georgia (Cole and Hemmerly 1981) and in Tennessee showed the aggregated pattern of distribution (Hemmerly et al. 1979; Henderson and Pekala 1980; Panvini 1991; Sadler and Hemmerly 1984). An aggregated non-random pattern is indicated when the spread of mistletoe in a host tree by avian vectors increases the chance of further infection of that tree and the infestation of other host trees of the same species. Abundance and density of American mistletoe are also correlated with the actual fact that more specific host trees are available for infestation in physiographic regions or provinces with specific geological substrates (e.g., black walnut and wild black cherry are more likely to be found in calcareous-based soils than acid soils, and blackgum typically is more abundant in siliceous-based soils). Host preferences in specific physiographic regions have been observed in Kentucky and Tennessee. Reed and Reed (1951) reported that geological formations within physiographic regions were an indicator of the species and abundance of mistletoe-infested host trees in Kentucky. In Tennessee, American mistletoe has been found to differentially parasitize various tree hosts among different physiographic regions (Anderson and Mundy 1980; Brown and Hemmerly 1979; Ferguson and Hemmerly 1976; Hemmerly 1981; Hemmerly et al. 1979; Hemmerly et al. 1987; Henderson and Pekala 1980; McKinney and Hemmerly 1977; Panvini 1991; Rucker and Hemmerly 1976; Sadler and Hemmerly 1984).

CONCLUSIONS

Our American mistletoe survey in Rockcastle County, Kentucky, has revealed that mistletoe has a considerable specificity for certain host trees in certain physiographic regions and not in other, contiguous regions (i.e., host tree species greatly infested in a certain region may not be parasitized or rarely infested when present in another). Factors determining host specificity probably include genetic parameters of both the mistletoe and the host trees in addition to local environmental, ecological, and physical conditions (Calder and Bernhardt 1983; Panvini 1991). Recommended future guidelines for American mistletoe research were outlined in Hemmerly (1989). Experimental and field studies by Clay et al. (1985), Glazner et al. (1988), May (1971, 1972), Panvini (1991), and Thomson and Mahall (1983) presented evidence for specific genetic races or ecotypes in *Phoradendron* spp. Ecotypes of American mistletoe could better explain the variations in host tree preferences and distributions. Further genetic studies are needed in American mistletoe to better understand ecological races and their interactions with various host trees.

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Checklist of the Vascular Flora of Pilot Knob State Nature Preserve, Powell County, Kentucky

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ABSTRACT

A floristic survey of the 262 ha Pilot Knob State Nature Preserve in northwest Powell County, Kentucky, was conducted from April 1999 to November 2002. The preserve is dominated by oak-hickory forests covering low conical and sharp-spined knobs divided by narrow valleys. Elevations in the preserve range from 244 m along Brush Creek to 439 m at the apex of Pilot Knob. An annotated checklist is provided of the vascular plants of the Preserve. A total of 504 species in 289 genera from 100 families was documented. The most important families based on number of species were Asteraceae (75), Poaceae (52), Fabaceae (26), Rosaceae (25) and Cyperaceae (22). Of the total collections, 51 species (10%) were non-native.

INTRODUCTION

Pilot Knob State Nature Preserve is a 262-ha natural area in the northwest corner of Powell County, ca. 5.5 km northwest of Clay City, Kentucky. As one of Kentucky's 40 state nature preserves, Pilot Knob is protected in perpetuity for scientific and educational purposes (KSNPC 2002). The preserve is located in a region of the state—the eastern Knobs that has received considerable attention from botanists (Braun 1950; Campbell et al. 1989; Fedders 1983; Godbey 1984; Grossman and Pittillo 1962; Jones and Thompson 1986; Muller and McComb 1986; Wharton 1945). Botanical research in Powell County has focused on the Red River Gorge in the Cumberland Plateau in the eastern third of the county (Braun 1950; Higgins 1970). Only one study, a vegetation of the Spencer-Morton preserve, has been completed in part of Pilot Knob preserve (Fedders 1983).

The objectives of our study were to (1) to document the vascular plants in the preserve, (2) add to the published knowledge of the Kentucky nature preserve system, (3) examine the stability of the woody flora of the preserve based on an early 1980s study, (4) add to the floristic knowledge of the eastern Knobs, and (5) produce a plant checklist usable for visitors to the Pilot Knob preserve.

THE STUDY AREA

Pilot Knob is located at latitude 37°55′30″N and longitude 84°57′30″W (Figure 1). The Pilot Knob prominence is visible to the north of the Mountain Parkway just west of the Clay City exit. The northern part of the preserve has two developed trails accessible from a graveled parking area at the northern end of Brush Creek Road. The southern portion of the preserve lacks foot trails but is accessible by a power line right-of-way maintenance road at the northern end of Millstone Road. The preserve is dominated largely by oak, oak-hickory, and oak-pine forests except for areas associated with an electric transmission line right-of-way, an FAA tower maintenance road on Rotten Point, and the flood plains associated with Brush Creek.

The Knobs is a distinct geologic and physiographic region of low conical hills that have been described by Braun (1950) as the Knobs Border Area of the Mixed Mesophytic Forest Region and by Fenneman (1938) as the Knobs Region subsection of the Highland Rim Sec-

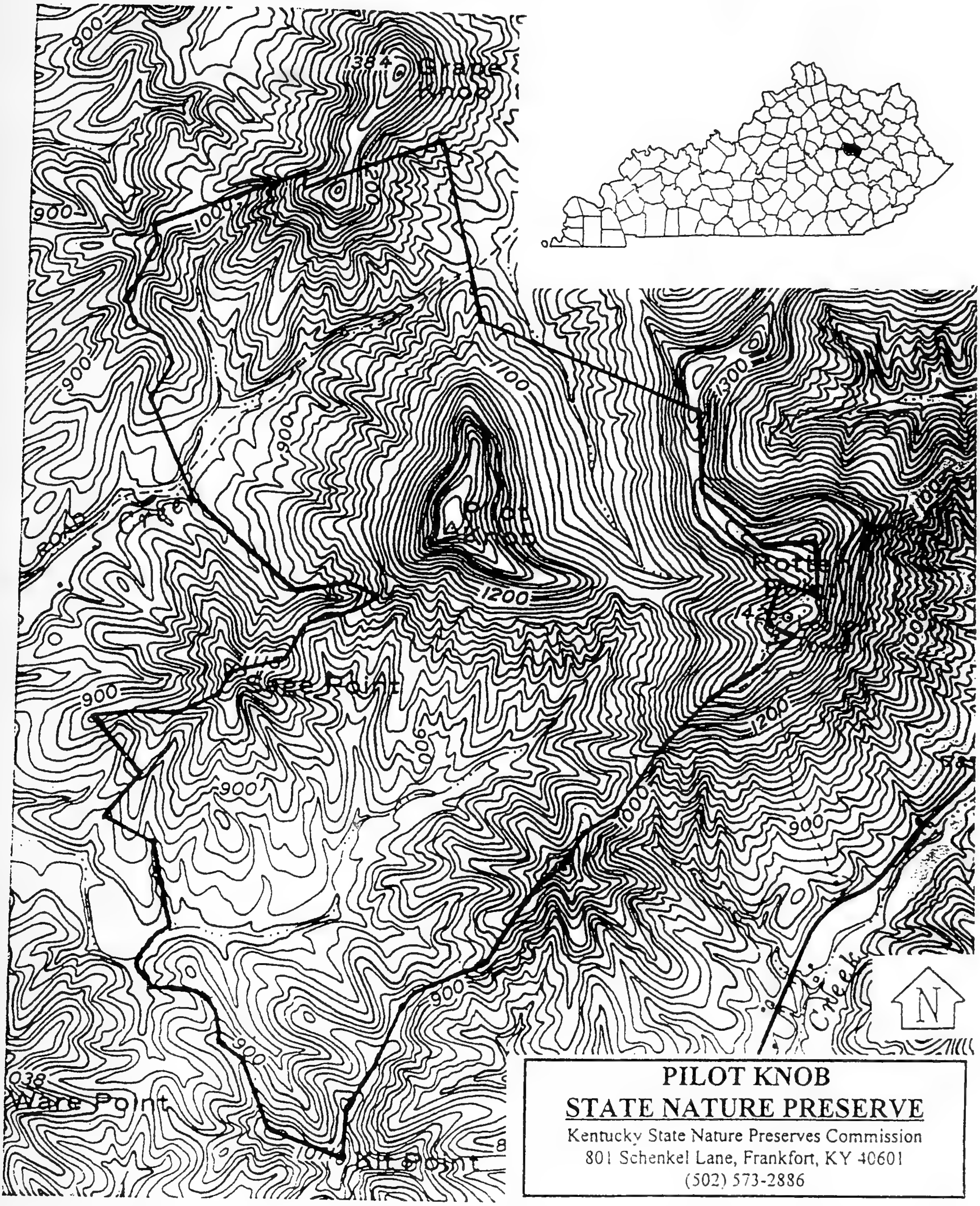

Figure 1. Pilot Knob State Nature Preserve, Powell County, Kentucky. Modified from Levee Quadrangle, (USGS 1965), and KSNPC maps. Inset shows location of Powell County.

tion of the Interior Low Plateau Province. More recently the Knobs have been interpreted as a single unit, the "Knobstone Escarpment" (Quarterman and Powell 1978). Weather resistant limestone or sandstone capstones prevent complete erosion of the hills thus leaving flat-topped or conical knobs distributed in a "U" shaped belt around the Bluegrass of Kentucky (Muller and McComb 1986).

Pilot Knob preserve contains both conical and flat-topped knobs. Pilot Knob, for which the preserve is named, rises to 439 m (1440 ft) and has a flat summit covering about 1 ha. The portion of Grape Knob summit within the preserve is also flat topped, rises to 402 m (1320 ft), and covers about ¼ ha. The flat areas of Rotten Point summit are outside the preserve, but maximum elevations of this knob within the preserve are 427 m (1400 ft). In the southern portion of the preserve the knobs are more gently sloped conical hills: Sage Point at 339 m (1113 ft), Kit Point at 326 m (1071 ft), and an unnamed knob northeast of Kit Point at 347 m (1140 ft). A broad open flood plain along the south fork of Brush Creek occurs between Sage Point and Kit Point. This valley's elevation is ca. 244 m (800 ft); its area is ca. 8 ha (USGS 1965).

The low, well-defined hills of the Knobs region are composed primarily of shales overlain with more resistant sandstone or limestone caprock (Ulack et al. 1998). In Pilot Knob preserve, lower elevations, as along the Brush Creek flood plains, are composed of New Albany Shale of Devonian and Mississippian age. These soft shales are dark gray to black and are highly carbonaceous and fissile. Lower slopes of knobs and even the summits of low conical knobs such as Kit Point and Sage Point (elevations 244–335 m) are composed of Mississippian age Borden Formation Nancy and Farmers Members. The Nancy Member is a shale and siltstone material that forms poorly drained clayey soils. The Farmers Member is composed of sandstones and shales. The upper slopes (elevations 335–396 m) of Grape Knob, Pilot Knob, and Rotten Point are Mississippian Borden Formation strata of the Cowbell Member. These Cowbell siltstones and shales form ledgy outcrops and weather to irregular blocks and sharp-edged chips and slabs. Pennsylvanian strata outcrops near the summits of Pilot Knob and Rotten Point are between 396 and 427 m. This Pennsylvanian Lee Formation material is composed of sandstone forming a conglomerate with pebbly quartz. This material is up to 38 m (125 ft) thick on Pilot Knob and forms the distinctive south-facing cliff of the knob. Pennsylvanian Breathitt Formation strata form outcrops at elevations above 427 m on Pilot Knob and Rotten Point. The summit of Grape Knob presents the only outcropping limestone material in the preserve. Here, Mississippian strata of the Borden Formation, Renfro Member composed of dolomite, dolomitic limestone, and limestone outcrop to form ledges on south- and southeast-facing slopes (McDowell 1978).

Soils within Pilot Knob preserve are Westbend Series Typic Hapludalfs. This series is a loamy or clayey textured, freely drained soil that is moderately deep to bed rock (USDA-NRCS 1999). Westbend Series soils in Powell County are derived from weathered Nancy Member siltstones and shales. Soils along the Brush Creek flood plains are Grigsby-Skidmore-Morehead Complex. These very deep, nearly level soils are composed of silt, sand, or gravelly loams. Although they are subject to late winter or early spring flooding, they have a high to moderate natural fertility and 2–4% organic matter and are suited to row crops. Low toe slopes above Brush Creek are of the Jessietown-Muse-Rohan Complex. These soils on 20–45% slopes are derived from black shale, are shallow, and are low in fertility and organic matter. Due to the shale fragments in the Rohan component, available water capacity in this complex is very low, as is pH (range 3.6–6.0). Soils of mid-slopes to tops of low conical knobs such as Kit Point are eroded Westbend silt-loam. These soils occur on 20–45% slopes and, although they have high available water capacity, they are highly eroded and are low in natural fertility, organic matter, and pH (range 3.6–6.5). Soils of upper slopes and the apex of Grape Knob, Pilot Knob, and Rotten Point are of the Carpenter-Bledsoe-Berks Complex on 20–70% slopes. This series exhibits a complex soil pattern because of soil and bedrock movement on the steep slopes. The Carpenter-Bledsoe component is a silt loam and a silt clay loam with high to moderately high natural fertility and organic matter. They tend to be deep, often 102–203 cm to bedrock, and are strongly acidic to mildly alkaline (pH 4.5–7.8). The Berks component is only moderately fertile, low in organic matter and available water capacity, and extremely to slightly acidic (pH 3.6–6.5) (Hayes 1993).

The climate at Pilot Knob preserve is a warm-summer subtype of the temperate continental climate. Summers are long, warm, and humid; winters are moderately cold (Trewartha and Horn 1980). Mean annual precipitation recorded at the Clay City Water Works, 7 km southeast of Pilot Knob, between 1971 and 2000, was 111.8 cm. Mean annual temperature recorded during the same period at Mt. Sterling, Kentucky, 16 km north of Pilot Knob, was 12.5°C, with a mean winter minimum of −5.5°C and a mean summer maximum of 29.9°C. The mean growing season during this period, recorded as days above 0°C, was 187 days (KCC 2003).

Pilot Knob preserve was assembled as two tracts over a 25-year period. The initial 125-ha tract was acquired by the Nature Conservancy in 1976 as the Spencer-Morton preserve (Fedders 1983). This tract comprises the northern half of the current Pilot Knob preserve. The Nature Conservancy and Eastern Kentucky University cooperatively managed the Spencer-Morton preserve from 1977 to 1985. In 1985 the tract was acquired by the Kentucky State Nature Preserves Commission (KSNPC) and rededicated as Pilot Knob State Nature Preserve.

In 1999 an additional 137 ha (Miller tract) was acquired by the KSNPC through the Kentucky Heritage Land Conservation Fund. This addition, comprising the southern half of the preserve, is similar in topography and forest composition to the original tract but lacks the elevation maximums found in the Spencer-Morton tract. The Miller tract also contains an old home site, an electric transmission line corridor and associated maintenance roads, and a broad flood plain meadow along the south fork of Brush Creek. This flood plain, not forested, differs from the closed canopy Brush Creek flood plains in the original tract. The existing stage of vegetation development and soil types present suggest that this flood plain was recently used for agricultural production. Pilot Knob State Nature Preserve currently consists of 262 hectares and is cooperatively managed by the KSNPC and Eastern Kentucky University (Martin 2002).

Land use history, including logging, in the 125 ha Spencer-Morton tract was described by Fedders, who also analyzed the vegetation and mapped forest communities (Fedders 1983). He recorded 39 tree, 12 shrub, and 4 woody vine species in the preserve but did not produce vouchers for these taxa. He described and mapped four community types on the preserve: oak communities, oak-hickory communities, hickory communities, and successional communities and concluded that the forest of the preserve was distinct from the Bluegrass Region and more closely related to the vegetation of the Cumberland Plateau.

Field observation indicated that forest communities of the Miller addition are similar to those on the original Spencer-Morton tract as described by Fedders (1983). Mid and upper slopes with north or east exposures are oak-hickory dominated with an understory of *Acer rubrum, Cornus florida,* and *Sassafras albidum.* Communities on south- and west-facing slopes are also oak-hickory dominated but often have a *Vaccinium-Smilax* understory. The riparian areas of the Miller tract, as along the south fork of Brush Creek, are dominated by *Platanus occidentalis,* and *Liquidambar styraciflua* with an understory of *Carpinus caroliniana, Corylus americana,* and *Lindera benzoin.* The open meadow along the south fork of Brush Creek supports a unique community in the preserve of native grasses (*Andropogon gerardii, Sorghastrum nutans*) and summer flowering composites (*Coreopsis tripteris, Eupatorium fistulosum, Helianthus hirsutus*).

METHODS

The floristic inventory of Pilot Knob was conducted over 29 field days between April 1999 and November 2002. The topography of the preserve was analyzed and efforts were made to survey all habitats during each part of the growing season. Completeness or likelihood of having collected the majority of species in the preserve was evaluated using the species-area formula of Wade and Thompson (1991). Sources consulted for taxonomic determinations included Cranfill (1980), Gleason and Cronquist (1991), and Radford et al. (1968). Voucher specimens were deposited at the Eastern Kentucky University Herbarium (EKY). For taxa with low numbers of observed individuals, no collections were made; these are noted as "observed only" in the annotated checklist.

RESULTS

A total of 504 species in 289 genera from 100 families was documented for Pilot Knob. Families containing the largest number of species were Asteraceae (75), Poaceae (52), Fabaceae (26), Rosaceae (25), and Cyperaceae (22). Of the total collections, 51 species (10%) were non-native. These 504 taxa represent 98.8% of the expected 510 taxa at Pilot Knob based on the species-area formula of Wade and Thompson (1991).

Although Braun (1950), Harker et al. (1981) and Wharton (1945) reported the presence of mixed mesophytic forest elements such as *Aesculus flava* and *Tilia heterophlla* occurring in the Knobs region, we found neither at Pilot Knob. Of the 31 rare species listed by Harker et al. (1981) for the Knobs we found only *Panax quinquefolius.* Similarly, bottom land species occurring in the Knobs according to Harker et al. (1981) and Wharton (1945)—e.g., *Acer negundo, Aesculus flava, Alnus rugosa, Cephalanthus occidentalis,* and *Populus deltoides*—were not found on the preserve. We found no area within the preserve exhibiting old-growth characteristics as outlined by Martin (1992). The 1999 Miller tract expansion added significantly different habitats from those in the original Spencer-Morton tract and thus increased the floristic richness of the preserve. Additionally, four glade areas were identified within the preserve that contain species found only in this habitat type. These glades occur on south and southeast facing upper slopes of Grape Knob, Rotten Point, and Pilot Knob and along the main Pilot Knob trail.

All 55 woody taxa reported in Fedders' (1983) vegetation study were redocumented in this effort except *Populus deltoides* and *Tilia heterophylla.* Although no *Populus deltoides* individuals were located, we did document *P. grandidentata* on the western edge of the Spencer-Morton tract and on the southwestern edge of the Miller tract on the preserve. This checklist expands the total number of woody plants documented for the Pilot Knob preserve to 107. No federally listed species, and only one state listed species, *Castanea dentata,* were found on the preserve (KSNPC 2000).

All taxa collected or observed are presented in the annotated checklist. Taxa are organized by families, genera, and species within major taxonomic divisions and classes (Gleason and Cronquist 1991). Non-native taxa are indicated by an asterisk (*), and degree of establishment (cultivated, persisting, waif, or naturalized) is given following Nesom (2000). An indication of the habitat, the relative abundance (frequency of occurrence) within the preserve, and the voucher number are provided. Terminology for relative abundance (abundant, frequent, occasional, infrequent, or rare) follows Rafaill and Thompson (2002). Herbarium voucher numbers are those of the senior author (W), the senior and second author (W&W), or all authors (W,W&G). Nomenclature largely follows Gleason and Cronquist (1991), but FNA (1997) and Kartesz (1994) were also used for some groups.

THE ANNOTATED CHECKLIST

LYCOPODIOPHYTA—LYCOPODIOPSIDA

LYCOPODIACEAE

Lycopodium digitatum Dillen.—Oak-pine woods, occasional. W,W&G 5251.

L. obscurum L.—Oak-pine woods, Sage Point, rare. Observed only.

ISOETOPSIDA

SELAGINELLACEAE

Selaginella apoda (L.) Spring—Wet meadow, rare. W&W 6590.

EQUISETOPHYTA

EQUISETACEAE

Equisetum arvense L.—Open areas at stream heads, occasional. W&W 5074.

POLYPODIOPHYTA

ADIANTACEAE

Adiantum pedatum L.—North facing mesic woods, Pilot Knob, occasional. W&W 6272.

ASPLENIACEAE

Asplenium montanum Willd.—Rock outcrops, Rotten Point, occasional. W&W 5018.

A. pinnatifidum Muhl.—Rock ledges, Pilot Knob, infrequent. W&W 5754; W 6724.

A. platyneuron (L.) Oakes—Oak woods, Pilot Knob, frequent. W&W 5761.

Athyrium filix-femina (L.) Roth—Seep, Pilot Knob, wet meadow, occasional. W&W 5735, 6855.

A. pycnocarpon (Sprengel) Tidestrom—North facing mesic woods, Pilot Knob, occasional. W&W 6273.

Dryopteris intermedia (Muhl.) A. Gray—Low woods, Millstone quarry trail, occasional. W&W 6058.

D. marginalis (L.) A. Gray—Low woods, intermittent drains, occasional. W,W&G 5223.

Polystichum acrostichoides (Michx.) Schott—Woods throughout, frequent. W&W 4929.

Thelypteris hexagonoptera (Michx.) Weatherby—Mesic woods, Millstone quarry trail, occasional. W&W 6059.

Woodsia obtusa (Sprengel) Torr.—Rock outcrops, Rotten Point, infrequent. W&W 5018X.

DENNSTAEDTIACEAE

Pteridium aquilinum (L.) Kuhn—Low, mesic woods, occasional. W 5721.

ONOCLEACEAE

Onoclea sensibilis L.—Wet meadow, infrequent. W&W 4930.

OPHIOGLOSSACEAE

Botrychium biternatum (Savigny) Underw.—Woods, low slopes, Kit Point, infrequent. W 6688.

B. dissectum Spreng.—Woods, low slopes, occasional. W&W 6044.

B. virginianum (L.) Swartz—Woods, Pilot Knob trail, occasional. W&W 5745.

OSMUNDACEAE

Osmunda cinnamomea L.—Seep, Pilot Knob, infrequent. W&W 5730.

O. regalis L.—Seep, Pilot Knob, infrequent. W&W 5729.

POLYPODIACEAE

Polypodium virginianum L.—Rock outcrops, Pilot Knob, occasional. W&W 4535.

PINOPHYTA

CUPRESSACEAE

Juniperus virginiana L.—Oak-pine woods, throughout, abundant. W,W&G 5291.

PINACEAE

Pinus echinata Miller—Oak-pine woods, Pilot Knob, Grape Knob, frequent. W&W 6270.

P. virginiana Miller—Rock ledges, Pilot Knob, Grape Knob, frequent. W&W 4533.

Tsuga canadensis (L.) Carrière—Bench above Brush Creek, rare. W 6891.

MAGNOLIOPHYTA—MAGNOLIOPSIDA

ACANTHACEAE

Ruellia caroliniensis (Walter) Steudel—Low slopes, Pilot Knob, occasional. W&W 6635.

ACERACEAE

Acer rubrum L.—Low slopes, woods throughout, abundant. W,W&G 5258.

A. saccharum Marshall—Oak-hickory woods, frequent. W&W 6260.

ANACARDIACEAE

Rhus aromatica Aiton—Open woods, Pilot Knob summit, rare. W&W 5766.

R. copallina L.—Open areas, wet meadow, occasional. W,W&G 5286.

R. glabra L.—Open areas, wet meadow, infrequent. W&W 4895.

Toxicodendron radicans (L.) Kuntze—Ruderal areas, woods, throughout, abundant. W&W 4891.

ANNONACEAE

Asimina triloba (L.) Dunal—Mesic woods, Kit Point, Pilot Knob, frequent. W,W&G 5238.

APIACEAE

Cryptotaenia canadensis (L.) DC.—Bench above Brush Creek, occasional. W 7447.

**Daucus carota* L. Naturalized.—Wet meadow, frequent. W,W&G 5275.

Osmorhiza claytonii (Michx.) C. B. Clarke—North slopes, Pilot Knob, occasional. W&W 6275.

Sanicula canadensis L.—Open areas, powerline right-of-way, frequent. W&W 5051.

S. gregaria E. Bickn.—Oak-hickory woods, Kit Point, occasional. W&W 6860.

S. smallii E. Bickn.—Mesic woods, Pilot Knob, occasional. W&W 6660.

Taenidia integerrima (L.) Drude—Oak ridge, Grape Knob, occasional. W&W 4667.

Thaspium barbinode (Michx.) Nutt.—Wet meadow, occasional. W,W&G 5261.

T. trifoliatum (L.) A. Gray—Mesic north-facing woods, wet meadow, occasional. W&W 5092; W 7872.

Zizia aptera (A. Gray) Fern.—Wet meadow, occasional. W&W 4952.

APOCYNACEAE

Apocynum cannabinum L.—Maintenance road, Rotten Point, occasional. W&W 5048.

AQUIFOLIACEAE

Ilex opaca Aiton—Dry oak woods, Pilot Knob slopes, rare. W&W 6895.

ARALIACEAE

Aralia racemosa L.—Low woods, Brush Creek, infrequent. W&W 6627.

A. spinosa L.—Dry woods, Kit Point, Rotten Point, occasional. W&W 5061.

Panax quinquefolius L.—Mesic woods, Pilot Knob, rare. W 6713.

ARISTOLOCHIACEAE

Aristolochia serpentaria L.—Trailside, Pilot Knob, infrequent. W&W 5222.

ASCLEPIADACEAE

Ampelamus albidus (Nutt.) Britton—Ruderal areas, Rotten Point, occasional. W&W 6303.

Asclepias quadrifolia Jacq.—Oak woods, Pilot Knob, infrequent. W&W 6274.

A. syriaca L.—Wet meadow, occasional. W&W 5032.

A. variegata L.—Mesic woods, Pilot Knob, infrequent. W&W 5777.

A. verticillata L.—Glade, Pilot Knob trail, rare. W 6699.

ASTERACEAE

Achillea millefolium L.—Wet meadow, ruderal areas, occasional. W&W 5035.

Ambrosia artemisiifolia L.—Rocky disturbed areas, Rotten Point, occasional. W&W 5054.

A. trifida L.—Ruderal areas, Pilot Knob trailhead, occasional. W&W 5720.

Antennaria plantaginifolia (L.) Richardson—Open wooded rock outcrops, Pilot Knob, occasional. W&W 4547.

A. solitaria Rydb.—Slopes, Pilot Knob, infrequent. W&W 6896.

Aster cordifolius L.—Oak-hickory woods, Grape Knob, occasional. W&W 6881.

A. dumosus L.—Wet meadow, ruderal areas, occasional. W&W 7800.

A. infirmus Michx.—Oak-pine woods, Kit Point, frequent. W,W&G 5222.

A. laevis L.—Low slopes, Kit Point, Pilot Knob, frequent. W&W 5539.

A. lateriflorus (L.) Britton—Mesic open areas, Brush Creek, occasional. W 7834.

A. macrophyllus L.—Mesic areas, Brush Creek, trailside, frequent. W&W 6026, 6642.

A. paternus Cronq.—Oak-hickory woods, Rotten Point, Kit Point, occasional. W&W 5008, 7443.

A. pilosus Willd.—Wet meadow, ruderal areas, occasional. W&W 6867.

A. racemosus Elliott—Wet meadow, ruderal areas, frequent. W&W 6877.

A. surculosus Michx.—Dry open areas, powerline right-of-way, occasional. W&W 6014.

A. undulatus L.—Mesic woods, Pilot Knob summit, occasional. W 7871.

Bidens bipinnatus L.—Mesic areas, Pilot Knob summit, occasional. W&W 6650.

B. frondosus L.—Mesic areas, Pilot Knob trail, occasional. W 6712.

B. polylepis S. F. Blake—Ruderal areas, wet meadow, occasional. W&W 6864.

Cacalia atriplicifolia L.—Rocky woods, Rotten Point, occasional. W&W 5050.

**Carduus nutans* L.—Naturalized. Rocky woods, disturbed areas, Rotten Point, infrequent. W&W 6305.

**Chrysanthemum leucanthemum* L.—Naturalized. Wet meadow, ruderal areas, occasional. W&W 4933.

Chrysopsis mariana (L.) Elliott—Glade, Pilot Knob trail, infrequent. W 6703.

**Cichorium intybus* L.—Naturalized. Ruderal areas, Pilot Knob trailhead, infrequent. W 7829.

**Cirsium vulgare* (Savi) Tenore—Naturalized. Powerline right-of-way, ruderal areas, occasional. W&W 6006.

C. discolor (Muhl.) Sprengel—Rocky disturbed areas, Rotten Point, infrequent. W&W 5056.

Conyza canadensis (L.) Cronq.—Powerline right-of-way, ruderal areas, abundant. W&W 6029.

Coreopsis major Walter—Upland woods, throughout, abundant. W&W 5772.

C. tripteris L.—Open areas, powerline right-of-way, abundant. W&W 6019.

Elephantopus carolinianus Willd.—Ruderal areas, Pilot Knob trailhead, infrequent. W 7738.

Erechtites hieraciifolia (L.) Raf.—Ruderal areas, throughout, occasional. W&W 6035.

Erigeron annuus (L.) Pers.—Ruderal areas, powerline right-of-way, abundant. W&W 5086.

E. philadelphicus L.—Ruderal areas, powerline right-of-way, abundant. W&W 4900.

E. strigosus Muhl.—Ruderal areas, powerline right-of-way, abundant. W&W 5027.

Eupatorium coelestinum L.—Mesic slopes above Brush Creek, infrequent. W&W 6873.

E. fistulosum Barratt—Open wet meadow, Brush Creek, abundant. W,W&G 5206.

E. pilosum Walter—Wet meadow, Brush Creek, infrequent. W,W&G 5205.

E. rotundifolium L.—Open areas, powerline right-of-way, infrequent. W&W 6017.

E. rugosum Houttuyn—Mesic woods, Pilot Knob summit, frequent. W&W 6655.

E. serotinum Michx.—Banks, gravels. Brush Creek, occasional. W&W 6016.

E. sessilifolium L.—Oak woods, Pilot Knob trail, occasional. W 7735.

Euthamia graminifolia (L.) Nutt.—Open areas, wet meadow, abundant. W,W&G 5208.

Gnaphalium obtusifolium L.—Wet meadow, powerline right-of-way, abundant. W&W 5543.

G. purpureum L.—Open areas, powerline right-of-way, frequent. W&W 5078.

Helenium flexuosum Raf.—Wet meadow and woods edge, infrequent. W,W&G 5243.

Helianthus divaricatus L.—Open areas, powerline right-of-way, frequent. W&W 6013.

H. microcephalus T. & G.—Wet meadow, woods edge, frequent. W,W&G 5221.

H. strumosus L.—Wet meadow, woods edge, occasional. W,W&G 5278.

Hieracium gronovii L.—Wet meadow, woods edge, frequent. W,W&G 5226.

H. venosum L.—Upland woods, throughout, frequent. W&W 4675.

Krigia biflora (Walter) S. F. Blake—Oak woods, Grape Knob, occasional. W&W 4668.

Lactuca biennis (Moench) Fern.—Woods, Pilot Knob trail, infrequent. W 7734.

L. canadensis L.—Wet meadow, woods edge, frequent. W&W 5740, 6870.

L. floridana (L.) Gaertner—Low woods, Pilot Knob trail, occasional. W 6737.

Liatris spicata (L.) Willd.—Rotten Point glade, infrequent. W&W 6009.

L. squarrulosa Michx.—Pilot Knob trail glade, infrequent. W 6701.

Polymnia uvedalia L.—Mesic northeast slope, Pilot Knob, infrequent. W&W 6644.

Prenanthes altissima L.—Wet meadow, woods edge, Sage Point, occasional. W&W 6879.

P. serpentaria Pursh—Oak-hickory woods, Pilot Knob trail glade, occasional. W 6709.

Pyrrhopappus carolinianus (Walter) DC.—Wet meadow, woods edge, occasional. W&W 5085.

Rudbeckia hirta L.—Wet meadow and woods edge, frequent. W&W 5083.

Senecio anonymus A. Wood—Seep, Pilot Knob trail, infrequent. W&W 6276.

S. aureus L.—Flood plain woods, Brush Creek, frequent. W&W 4647.

S. obovatus Muhl.—Flood plain woods, Kit Point, frequent. W&W 6264.

Solidago canadensis L.—Wet meadow, woods edge, frequent. W,W&G 5230; W&W 5544.

S. caesia L.—Oak-hickory woods, throughout, frequent. W&W 5546.

S. erecta Pursh—Wet meadow along Brush Creek, occasional. W&W 5542, 6862.

S. hispida Muhl.—Pilot Knob glade, infrequent. W 7877.

S. nemoralis Aiton—Open areas, powerline right-of-way, frequent. W&W 6021.

S. odora Aiton—Pilot Knob trail glade, infrequent. W 7732.

S. rugosa Miller—Wet meadow along maintenance road, infrequent. W&W 5541.

S. ulmifolia Muhl.—Rotten Point glade, occasional. W&W 7795.

**Taraxacum officinale* Weber ex Wiggers—Naturalized. Ruderal areas, wet meadow, frequent. W&W 6254.

**Tussilago farfara* L.—Naturalized. Gravels, Brush Creek, infrequent. W&W 6256.

Vernonia gigantea (Walter) Trel.—Wet meadow and woods edge, frequent. W&W 6073.

BALSAMINACEAE

Impatiens capensis Meerb.—Wet meadow, Brush Creek, occasional. W,W&G 5273.

BERBERIDACEAE

Podophyllum peltatum L.—Mesic areas, Brush Creek, frequent. W&W 6259.

BETULACEAE

Betula nigra L.—Banks, Brush Creek, rare. W&W 6619.

Carpinus caroliniana Walter—Banks, low woods, Brush Creek, occasional. W&W 6067.

Corylus americana Walter—Low woods, Brush Creek, abundant. W,W&G 5289.

Ostrya virginiana (Miller) K. Koch—Banks, low woods, Brush Creek, occasional. W&W 6066.

BIGNONIACEAE

Bignonia capreolata L.—Oak woods, Kit Point, infrequent. W 7833.

Campsis radicans (L.) Seemann—Woods edge, throughout, abundant. W&W 4953.

**Paulownia tomentosa* (Thunb.) Steudel—Naturalized. Wooded margin, powerline right-of-way, rare. W 7730.

BORAGINACEAE

Cynoglossum virginianum L.—Woods, Pilot Knob trail, occasional. W&W 5758.

Hackelia virginiana (L.) I. M. Johnston—Open woods, Pilot Knob summit, rare. W&W 6651.

BRASSICACEAE

Arabis laevigata (Muhl.) Poiret—Rock outcrops, Grape Knob, occasional. W&W 4680.

**Barbarea vulgaris* R. Br.—Naturalized. Ruderal areas, wet meadow, occasional. W&W 4896.

Cardamine angustata O. E. Schulz—Mesic woods, Pilot Knob summit, frequent. W&W 4545.

C. concatenata (Michx.) O. Schwarz—Mesic woods, Pilot Knob summit, frequent. W&W 4536.

C. hirsuta L.—Trailside areas, Pilot Knob, occasional. W&W 4534.

C. pensylvanica Muhl.—Bench above Brush Creek, occasional. W&W 6947.

Lepidium virginicum L.—Ruderal areas, Pilot Knob trail, occasional. W&W 5734.

CAESALPINIACEAE

Cercis canadensis L.—Woods, throughout, abundant. W,W&G 5209.

Chamaecrista fasciculata (Michx.) Greene—Maintenance road, wet meadow, abundant. W,W&G 5204; W&W 6000.

C. nictitans (L.) Moench—Maintenance road, wet meadow, abundant. W&W 6024.

CAMPANULACEAE

Campanula americana L.—Mesic woods, Pilot Knob, occasional. W&W 6649.

Lobelia inflata L.—Wet meadow, frequent. W,W&G 5233.

L. puberula Michx.—Wet meadow, low slopes, Kit Point, frequent. W,W&G 5229.

L. spicata Lam.—Low slopes above Brush Creek, occasional. W&W 5094.

Triodanis perfoliata (L.) Nieuwl.—Woods, Pilot Knob trail, occasional. W&W 5752.

CAPRIFOLIACEAE

**Lonicera japonica* Thunb.—Naturalized. Ruderal areas, Pilot Knob trail, abundant. W&W 5531.

**L. maackii* (Rupr.) Maxim.—Naturalized. Summit woods, Grape Knob, Pilot Knob, rare. W&W 6640.

Sambucus canadensis L.—Brush Creek flood plain, abundant. W&W 6252.

Symphoricarpos orbiculatus Moench—Open woods, Pilot Knob summit, infrequent. W&W 5757.

Triosteum aurantiacum E. Bickn.—Oak woods, Pilot Knob, occasional. W&W 6271.

Viburnum acerifolium L.—Mesic woods, Pilot Knob, Kit Point, infrequent. W&W 5075.

V. prunifolium L.—Low woods, wet meadow, Brush Creek, infrequent. W,W&G 5253.

V. rufidulum Raf.—Dry ridges, Grape Knob, frequent. W&W 4670.

CARYOPHYLLACEAE

**Cerastium vulgatum* L.—Naturalized. Maintenance road, Rotten Point, occasional. W&W 6939.

Paronychia canadensis (L.) A. Wood—Pilot Knob glade, infrequent. W&W 5741.

Silene caroliniana Walter—Shale bank, Sage Point, rare. W&W 6255.

S. rotundifolia Nutt.—Rock outcrops, Rotten Point, infrequent. W&W 5010.

S. stellata (L.) Aiton f.—Woods edge, Sage Point, occasional. W&W 6591.

Stellaria media (L.) Villars—Riparian woods, Brush Creek, frequent. W&W 4543.

S. pubera Michx.—Riparian woods, Brush Creek, frequent. W&W 4649.

CELASTRACEAE

Celastrus scandens L.—Rock outcrops, Rotten Point, infrequent. W&W 5046.

Euonymus atropurpureus Jacq.—Oak-hickory woods, Pilot Knob trail, occasional. W&W 5759.

**E. fortunei* (Turcz.) Hand.-Mazz.—Naturalized. Flood plain woods, Brush Creek, rare. W&W 7882.

CHENOPODIACEAE

**Chenopodium album* L.—Naturalized. Pilot Knob trail, infrequent. W&W 5725.

C. simplex (Torr.) Raf.—Rotten Point glade, infrequent. W&W 7793.

CISTACEAE

Lechea racemulosa Michx.—Pilot Knob glade, rare. W 7812.

CLUSIACEAE

Hypericum gentianoides (L.) BSP.—Open areas, powerline right-of-way, abundant. W&W 6043.

H. mutilum L.—Maintenance road to wet meadow, abundant. W&W 6041.

H. punctatum Lam.—Wooded slopes, Sage Point, occasional. W&W 6615.

H. stragulum P. Adams & Robson—Oak-pine woods, trail, Pilot Knob, frequent. W,W&G 5202.

CONVOLVULACEAE

Calystegia sepium (L.) R. Br.—Maintenance road along Brush Creek, occasional. W,W&G 5234.

Ipomoea lacunosa L.—Ruderal areas, Brush Creek, occasional. W 7719.

I. pandurata (L.) G. Meyer—Maintenance road, Brush Creek, occasional. W&W 6075.

**I. purpurea* (L.) Roth—Naturalized. Maintenance road, wet meadow, occasional. W&W 5026, 6076.

CORNACEAE

Cornus drummondii C.A. Meyer—Maintenance road, Rotten Point, rare. W&W 6940.

C. florida L.—Woods edge, wet meadow, frequent. W,W&G 5293.

Nyssa sylvatica Marshall—Oak-pine woods, Kit Point, Sage Point, abundant. W,W&G 5287.

CRASSULACEAE

Sedum ternatum Michx.—Rock outcrops, Pilot Knob, occasional. W&W 5768.

CUSCUTACEAE

Cuscuta cuspidata Engelm.—Woods edge, wet meadow, infrequent. W&W 6046.

C. gronovii Willd.—Brush Creek, infrequent. W&W 7799.

EBENACEAE

Diospyros virginiana L.—Oak-pine woods, Kit Point, Sage Point, abundant. W,W&G 4926.

ERICACEAE

Epigaea repens L.—Rock outcrops, Rotten Point, infrequent. W&W 6308.

Gaultheria procumbens L.—Open oak-pine woods, Millstone trail, infrequent. W&W 6051.

Gaylussacia baccata (Wangenh.) K. Koch—Rock outcrops, open woods, Pilot Knob, infrequent. W&W 5738.

Kalmia latifolia L.—Rocky woods, ridge crests, Pilot Knob, Rotten Point, frequent. W&W 4541.

Oxydendrum arboreum (L.) DC.—Woods, throughout, abundant. W&W 5065.

Vaccinium corymbosum L.—Rocky woods, Rotten Point, infrequent. W&W 5049, 6298.

V. pallidum Aiton—Oak-heath woods, Pilot Knob, Grape Knob, abundant. W&W 4679, 5770.

V. stamineum L.—Low slopes, Kit Point, frequent. W&W 4957.

EUPHORBIACEAE

Acalypha gracilens A. Gray—Maintenance road through wet meadow, frequent. W&W 6032.

A. virginica L.—Maintenance road through wet meadow, frequent. W&W 6069.

Euphorbia corollata L.—Maintenance road through wet meadow, frequent. W,W&G 5249.

E. nutans Lagasca—Ruderal areas, powerline right-of-way, occasional. W&W 6007; W 6673.

FABACEAE

Amphicarpaea bracteata (L.) Fern.—Low woods, Brush Creek, frequent. W&W 6630, W 6696.

Apios americana Medikus—Maintenance road, wet meadow, occasional. W&W 6074, 6617.

Clitoria mariana L.—Bench above Brush Creek, rare. W 7454.

**Coronilla varia* L.—Naturalized. Maintenance road, Rotten Point, occasional. W&W 5043.

Desmodium glabellum (Michx.) DC.—Low woods, Pilot Knob trailhead, infrequent. W 6742.

D. glutinosum (Muhl.) A. Wood—Woods, Pilot Knob trail, occasional. W&W 5733.

D. nudiflorum (L.) DC.—Woods, Millstone quarry trail, occasional. W&W 6054.

D. paniculatum (L.) DC.—Low woods, Pilot Knob trail, occasional. W 6741.

D. rotundifolium DC.—Woods, Pilot Knob summit, infrequent. W&W 6638.

**Lespedeza cuneata* (Dum. Cours.) G. Don—Naturalized. Ruderal areas, wet meadow, frequent. W&W 6316.

L. hirta (L.) Hornem.—Dry open ridge crests, right-of-way, infrequent. W&W 6011.

L. intermedia (S. Wats.) Britton—Oak-hickory woods, Grape Knob, occasional. W&W 6887.

L. procumbens Michx.—Shale bank, Brush Creek, infrequent. W&W 6576.

L. repens (L.) Barton—Oak-hickory woods, Kit Point, infrequent. W&W 6853.

**L. striata* (Thunb.) Hook. & Arnott—Naturalized. Ruderal areas, wet meadow, abundant. W&W 5535, 6071.

L. violacea (L.) Pers.—Ruderal areas, wet meadow, abundant. W&W 5536, 6077.

L. virginica (L.) Britton—Open areas, powerline right-of-way, infrequent. W 7723.

**Melilotus alba* Medikus—Naturalized. Maintenance road, Rotten Point, occasional. W 6677.

Orbexilum pedunculatum (Miller) Rydb.—Wet meadow, low slopes, Pilot Knob, abundant. W&W 4940, 6317.

Robinia pseudoacacia L.—Woods, Kit Point, Pilot Knob, frequent. W,W&G 5294.

Strophostyles helvula (L.) Elliott—Shale bank, Brush Creek, rare. W&W 6598.

S. umbellata (Muhl.) Britton—Open areas, powerline right-of-way, infrequent. W 7726.

Tephrosia virginiana (L.) Pers.—Ridges, Kit Point, rare. W 7440.

**Trifolium pratense* L.—Naturalized. Ruderal areas, maintenance roads, frequent. W 6733.

**T. repens* L.—Naturalized. Maintenance roads, frequent. W&W 4968.

Vicia caroliniana Walter—Open woods, Pilot Knob trail, frequent. W&W 4555.

FAGACEAE

Castanea dentata (Marshall) Borkh.—Rocky woods, Rotten Point, Pilot Knob, infrequent. W&W 5012.

Fagus grandifolia Ehrh.—Slope above Brush Creek, abundant. W,W&G 5264.

Quercus alba L.—Oak-hickory woods, Kit Point, Rotten Point, abundant. W,W&G 5256.

Q. coccinea Muenchh.—Low slopes, Sage Point, abundant. W&W 5059, 5098; W,W&G 5259.

Q. falcata Michx.—Wooded terrace, Brush Creek, rare. W 7716.

Q. imbricaria Michx.—Woods, Kit Point, frequent. W&W 4964.

Q. marilandica Muenchh.—Glade, Grape Knob, Pilot Knob, frequent. W&W 4662, 4963.

Q. montana Willd.—Ridge crest, Pilot Knob, Grape Knob, abundant. W,W&G 5255.

Q. rubra L.—Woods above Brush Creek, frequent. W,W&G 5282.

Q. stellata Wangenh.—Oak-pine woods, Kit Point, occasional. W,W&G 5218.

Q. velutina Lam.—Oak woods, Grape Knob, Kit Point, frequent. W&W4677, 6045.

FUMARIACEAE

Corydalis flavula (Raf.) DC.—Open woods, Pilot Knob summit, abundant. W&W 4539.

GENTIANACEAE

Frasera caroliniensis Walter—Glade, Grape Knob, infrequent. W 7825.

Sabatia angularis (L.) Pursh—Wet meadow, Brush Creek, occasional. W,W&G 5279.

GERANIACEAE

Geranium carolinianum L.—Wet meadow, Brush Creek, occasional. W&W 4960.

G. maculatum L.—Riparian woods, Brush Creek, occasional. W&W 4650.

HAMAMELIDACEAE

Hamamelis virginiana L.—Wet meadow, banks, Brush Creek, frequent. W,W&G 5254.

Liquidambar styraciflua L.—Low woods, wet meadow, Brush Creek, abundant. W,W&G 5288.

HYDRANGEACEAE

**Deutzia scabra* Thunb.—Persisting. Old house site, Brush Creek, rare. W 7451.
Hydrangea arborescens L.—Banks, ledges, Brush Creek, frequent. W,W&G 5262.

JUGLANDACEAE

Carya glabra (Miller) Sweet—Oak-hickory woods, Sage Point, Pilot Knob, abundant. W&W 5055, 6060; W,W&G 5219.
C. ovata (Miller) K. Koch—Oak woods, dry ridges, Grape Knob, occasional. W&W 4687.
C. tomentosa (Poiret) Nutt.—Woods, Millstone quarry trail, Kit Point, frequent. W,W&G 5285; W&W 5285.
Juglans nigra L.—Low woods, Pilot Knob trail, occasional. W&W 5755.

LAMIACEAE

Collinsonia canadensis L.—Low woods, Pilot Knob trail, infrequent. W 6748.
Cunila origanoides (L.) Britton—Oak-pine woods, Sage Point, abundant. W,W&G 5244.
Hedeoma pulegioides (L.) Pers.—Ruderal areas, Rotten Point, infrequent. W 6676.
Lycopus virginicus L.—Wet meadow, stream heads, occasional. W&W 6025.
Monarda fistulosa L.—Open, mesic, powerline right-of-way, occasional. W&W 5072.
M. virgata Raf.—Glade, Grape Knob, infrequent. W 7824X.
**Perilla frutescens* (L.) Britton—Naturalized. Ruderal areas, maintenance road, Rotten Point, occasional. W&W 6295.
Prunella vulgaris L.—Mesic woods, drainages, Pilot Knob, occasional. W&W 6288.
Pycnanthemum pycnanthemoides (Leavenw.) Fern.—Woods edge, wet meadow, infrequent. W,W&G 5228.
P. tenuifolium Schrader—Woods edge, wet meadow, infrequent. W,W&G 5231.
Salvia lyrata L.—Wet meadow along Brush Creek, frequent. W&W 4935.
Scutellaria elliptica Muhl.—Rocky woods, Rotten Point, occasional. W&W 5015.
S. incana Biehler—Mesic areas, Pilot Knob trail, frequent. W&W 5774.
S. nervosa Pursh—Mesic low slopes, Sage Point, infrequent. W&W 4970.
Stachys cordata Riddell—Wet meadow along Brush Creek, infrequent. W&W 5022.

LAURACEAE

Lindera benzoin (L.) Blume—Mesic woods, flood plains, abundant. W,W&G 5263.
Sassafras albidum (Nutt.) Nees—Wet meadow, woods, throughout, abundant. W,W&G 5214.

LINACEAE

Linum striatum Walter—Shale bank, low slopes, Sage Point, occasional. W&W 6602.

MAGNOLIACEAE

Liriodendron tulipifera L.—Low woods, drainages, wet meadow, Pilot Knob, abundant. W,W&G 5290.

MALVACEAE

**Hibiscus syriacus* L.—Persisting. Old house site, Brush Creek, rare. W 7448.
Sida spinosa L.—Open, mesic, powerline right-of-way, occasional. W&W 6068.

MELASTOMATACEAE

Rhexia mariana L.—Open, wet meadow, infrequent. W,W&G 5246.
R. virginica L.—Open, wet meadow, frequent. W&W 6579.

MENISPERMACEAE

Cocculus carolinus (L.) DC.—Riparian woods, Brush Creek, rare. W,W&G 5292.

MONOTROPACEAE

Monotropa uniflora L.—Low slopes, Sage Point, infrequent. W&W 6875.

MORACEAE

Morus rubra L.—Woods, Pilot Knob, Rotten Point, frequent. W,W&G 5215; W&W 7792.

OLEACEAE

Fraxinus americana L.—Oak woods, slopes, Grape Knob, frequent. W&W 4688, 4897.
F. pennsylvanica Marshall—Low slopes, Kit Point, occasional. W&W 6249.
F. profunda (Bush) Bush—Wet meadow along Brush Creek, rare. W,W&G 5235.

ONAGRACEAE

Circaea lutetiana L.—Open wet meadow, woods edge, frequent. W&W 5077.

Ludwigia alternifolia L.—Open wet meadow, infrequent. W&W 5082.

Oenothera biennis L.—Ruderal areas, wet meadow, infrequent. W 6687.

OROBANCHACEAE

Conopholis americana (L.) Wallr.—Oak woods, Grape Knob ridge, rare. W&W 4683.

OXALIDACEAE

Oxalis dillenii Jacq.—Low woods, Brush Creek, occasional. W,W&G 5274.

O. stricta L.—Ruderal areas, wet meadow, frequent. W&W 4946.

O. grandis Small—Woods, intermittent drainages, Pilot Knob, occasional. W&W 6289.

O. violacea L.—Flood plain, Brush Creek, occasional. W&W 4656.

PASSIFLORACEAE

Passiflora lutea L.—Rocky woods, Rotten Point, occasional. W&W 5045.

PHYTOLACCACEAE

Phytolacca americana L.—Ruderal areas, wet meadow, occasional. W&W 4959.

PLANTAGINACEAE

Plantago rugelii Decne.—Ruderal areas, maintenance road, Rotten Point, occasional. W&W 5053.

P. virginica L—Maintenance road, wet meadow, frequent. W&W 4948.

PLATANACEAE

Platanus occidentalis L.—Brush Creek, flood plains, abundant. W,W&G 5283.

POLEMONIACEAE

Phlox maculata L.—Wet meadow, abundant. W&W 5031.

P. paniculata L.—Oak-pine woods, Pilot Knob, occasional. W&W 6626.

P. pilosa L.—Low thickets, Pilot Knob trail, occasional. W&W 6269.

P. subulata L.—Oak woods, dry ridges, Grape Knob, occasional. W&W 4685.

POLYGALACEAE

Polygala sanguinea L.—Open, wet meadow, frequent. W,W&G 5236.

P. ambigua Nutt.—Open wet meadow, ditch banks, infrequent. W&W 6589.

POLYGONACEAE

Polygonum cespitosum Blume—Creek bank, Brush Creek, occasional. W&W 6063.

P. punctatum Elliott—Low woods, Pilot Knob trail, occasional. W 6738.

P. sagittatum L.—Wet meadow, drainages, frequent. W&W 5042.

P. scandens L.—Openings, Pilot Knob summit, occasional. W&W 5767.

P. virginianum L.—Low woods, Pilot Knob, frequent. W&W 6022.

Rumex acetosella L.—Ruderal areas, maintenance road, frequent. W&W 4961.

R. crispus L.—Disturbed margins, Pilot Knob trail, occasional. W&W 5726.

PORTULACACEAE

Claytonia virginica L.—Open woods, Pilot Knob summit, frequent. W&W 4548.

PRIMULACEAE

Lysimachia lanceolata Walter—Wet meadow, infrequent. W&W 5036.

L. quadrifolia L.—Wet meadow, infrequent. W&W 5096.

PYROLACEAE

Chimaphila maculata (L.) Pursh—Oak woods, slopes, Grape Knob, infrequent. W&W 4665.

RANUNCULACEAE

Anemone virginiana L.—Low woods, Pilot Knob trail, infrequent. W 6727.

Anemonella thalictroides (L.) Spach—Mesic woods, Pilot Knob summit, occasional. W&W 4537.

Cimicifuga racemosa (L.) Nutt.—North slopes, Pilot Knob, occasional. W&W 5760; W 7874.

Clematis virginiana L.—Flood plain woods, Pilot Knob, rare. W&W 7881.

Ranunculus hispidus Michx.—Low woods, Brush Creek, occasional. W&W 4688X.

Thalictrum pubescens Pursh—Low slopes, Kit Point, Sage Point, infrequent. W&W 6002, 6620.

T. revolutum DC.—Open woods, Pilot Knob summit, infrequent. W&W 5762.

RHAMNACEAE

Ceanothus americanus L.—Rocky woods, Pilot Knob, rare. W&W 5736.

Rhamnus caroliniana Walter—Rotten Point woodland glade, rare. W 6668.

ROSACEAE

Agrimonia rostellata Wallr.—Wooded slopes, Pilot Knob, frequent. W&W 6050.

Amelanchier arborea (Michx. f.) Fern.—Woods, throughout, abundant. W,W&G 5217.

Aronia melanocarpa (Michx.) Elliott—Rock outcrops, Rotten Point, rare. W&W 5014.

Crataegus coccinea L.—Woods edge, low slopes, Kit Point, infrequent. W,W&G 5203.

C. punctata Jacq.—Dry ridge, Grape Knob, infrequent. W 7828.

Fragaria virginiana Duchesne—Millstone quarry trail, occasional. W 6725.

Geum canadense Jacq.—Woods edge, wet meadow, frequent. W&W 6593.

Porteranthus stipulatus (Muhl.) Britton—Woods, Kit Point, Rotten Point, abundant. W&W 5070.

Potentilla canadensis L.—Open woods, Pilot Knob, occasional. W&W 4554X.

P. norvegica L.—Ruderal areas, maintenance road, occasional. W&W 6577.

P. simplex Michx.—Ruderal areas, maintenance road, occasional. W&W 4913.

Prunus americana Marshall—Open woods, Pilot Knob summit, infrequent. W&W 4546.

**P. cerasus* L. —Persisting. Old house site, Brush Creek, rare. W 7449.

P. mexicana S. Wats.—Rocky woods, Rotten Point, infrequent. W&W 4682, 5057.

P. serotina Ehrh.—Woods, throughout, frequent. W,W&G 5220.

**Pyrus calleryana* Dcne.—Naturalized. Wet meadow, maintenance road, rare. W&W 7883.

P. coronaria L.—Wet meadow, maintenance road, infrequent. W&W 5030.

Rosa carolina L.—Dry shale bank, Kit Point, occasional. W&W 6004.

**R. multiflora* Thunb.—Naturalized. Pilot Knob trailhead, occasional. W&W 5719.

R. setigera Michx.—Open wet meadow, infrequent. W&W 5021.

Rubus allegheniensis T. C. Porter—Woods edge, wet meadow, occasional. W&W 4911, 5073.

R. argutus Link—Open wet meadow, occasional. W&W 5095.

R. flagellaris Willd.—Ruderal areas, wet meadow, maintenance road, infrequent. W&W 6607.

R. hispidus L.—Open woods, Pilot Knob summit, occasional. W&W 5748.

R. occidentalis L.—Open woods, Pilot Knob summit, occasional. W&W 5753.

RUBIACEAE

Diodia teres Walter—Dry, open powerline right-of-way, occasional. W&W 6018.

Galium aparine L.—Ruderal areas, maintenance road, Rotten Point, frequent. W 6682.

G. circaezans Michx.—Wooded slopes, Kit Point, occasional. W&W 4971.

G. triflorum Michx.—Wet meadow, low slopes, Kit Point, frequent. W,W&G 5213.

Hedyotis caerulea (L.) Hook.—Rock outcrops, Pilot Knob summit, frequent. W&W 4550, 6053.

H. canadensis (Willd.) Fosb.—Wet meadow, Brush Creek, occasional. W&W 4894.

H. purpurea (L.) T. & G.—Wet meadow, Brush Creek, occasional. W&W 5097.

Mitchella repens L.—Rock outcrops, Rotten Point, infrequent. W&W 5016.

SALICACEAE

Populus grandidentata Michx.—Low woods, Pilot Knob trail, wet meadow, infrequent. W&W 6575, 6633, 6634.

Salix humilus Marshall—Open areas, wet meadow, infrequent. W&W 4924, 6003.

S. nigra Marshall—Banks, Brush Creek, infrequent. W&W 4903.

SAXIFRAGACEAE

Heuchera americana L.—Ledges, rock outcrops, Pilot Knob, occasional. W&W 6612.

H. villosa Michx.—Rock face ledges, Pilot Knob, occasional. W&W 6643; W 7879.

Penthorum sedoides L.—Stream heads, wet meadow, infrequent. W&W 6005.

Saxifraga virginiensis Michx.—Ledges, rock outcrops, Pilot Knob, infrequent. W&W 4538.

SCROPHULARIACEAE

Agalinis gattingeri (Small) Small—Pilot Knob trail glade, rare. W 6698.

A. tenuifolia (M. Vahl) Raf.—Wet meadow, Kit Point, abundant. W&W 6866.

Aureolaria virginica (L.) Pennell—Oak-pine woods, Kit Point, occasional. W,W&G 5210.

Mimulus ringens L.—Stream heads, wet meadow, infrequent. W,W&G 5272.

Pedicularis canadensis L.—Mesic woods, Brush Creek, frequent. W&W 4654.

Penstemon hirsutus (L.) Willd.—Shale bank, Brush Creek, infrequent. W&W 4956.

**Veronica arvensis* L.—Naturalized. Bench above Brush Creek, infrequent. W&W 6946.

**V. officinalis* L.—Naturalized. Open areas, Millstone quarry trail, infrequent. W&W 6049.

SOLANACEAE

Physalis pubescens L.—Rocky woods, Rotten Point, infrequent. W&W 6304.

Solanum carolinense L.—Open wet meadow, Brush Creek, occasional. W&W 4949.

S. nigrum L.—Rock outcrops, Pilot Knob summit, infrequent. W&W 6645.

ULMACEAE

Celtis occidentalis L.—Woods, Pilot Knob summit, occasional. W&W 5751, 5764.

Ulmus americana L.—Open woods, Pilot Knob summit, occasional. W&W 4540.

U. rubra Muhl.—Wet meadow, Brush Creek, occasional. W&W 4902.

URTICACEAE

Boehmeria cylindrica (L.) Swartz—Gravel bars, Brush Creek, frequent. W,W&G 5252.

Parietaria pensylvanica Muhl.—Trailside, Pilot Knob summit, occasional. W&W 5724.

Pilea pumila (L.) A. Gray—Glade, Pilot Knob summit, occasional. W 6716.

VERBENACEAE

Phryma leptostachya L.—Woods, northeast face, Pilot Knob, infrequent. W&W 6664.

Verbena urticifolia L.—Open wet meadow, Brush Creek, frequent. W,W&G 5270.

VIOLACEAE

**Viola arvensis* Murray—Naturalized. Trailside, Pilot Knob summit, rare. Observed only.

V. palmata L.—Oak woods, dry ridge, Grape Knob, infrequent. W&W 4663.

V. pedata L.—Oak woods, dry ridge, Grape Knob, infrequent. W&W 4664.

V. sororia Willd.—Open woods, Pilot Knob summit, occasional. W&W 4556.

VITACEAE

Parthenocissus quinquefolia (L.) Planchon—Woods, open areas, throughout, frequent. W&W 5732.

Vitis aestivalis Michx.—Wooded slopes, Rotten Point, frequent. W&W 5044.

V. vulpina L.—Woods, Pilot Knob, frequent. W&W 6639.

MAGNOLIOPHYTA—LILIOPSIDA

AGAVACEAE

**Yucca filamentosa* L.—Naturalized. Low slopes, Sage Point, rare. W&W 6595.

ARACEAE

Arisaema triphyllum (L.) Schott—Wet meadow, occasional. W,W&G 5271.

COMMELINACEAE

Tradescantia virginiana L.—Woods, low slopes, Kit Point, occasional. W&W 4917.

CYPERACEAE

Bulbostylis capillaris (L.) C. B. Clarke—Pilot Knob summit glade, rare. W 6718.

Carex amphibola Steudel—Wet meadow, low woods, occasional. W&W 4936, 5749.

C. blanda Dewey—Wet meadow, occasional. W&W 4912.

C. complanata Torr. & Hook.—Wet meadow, Brush Creek, occasional. W&W 4967, 5104.

C. crinita Lam.—Wet meadow, Brush Creek, occasional. W&W 4955.

C. digitalis Willd.—Oak woods, Grape Knob; rocky woods, Rotten Point, infrequent. W&W 4674, 6302.

C. frankii Kunth—Openings, riparian woods, infrequent. W&W 6629.

C. hirsutella Mackenzie—Rocky woods, Rotten Point, occasional. W&W 4908, 6310.

C. lupulina Muhl.—Mesic areas, powerline, occasional. W&W 5079.

C. muhlenbergii Schk.—Open areas, Pilot Knob trail, infrequent. W&W 5742.

C. oligocarpa Schk.—Flood plain woods, Pilot Knob, occasional. W&W 4659.

C. pensylvanica Lam.—Rocky woods, Rotten Point, infrequent. W&W 6300.

C. picta Steudel—Wet meadow, infrequent. W&W 4920.

C. platyphylla Carey—Riparian woods, occasional. W&W 4653.

C. rosea Schk.—Wet meadow, occasional. W&W 4972.

C. virescens Muhl.—Glade, rock outcrops, Pilot Knob, infrequent. W 6722.

C. vulpinoidea Michx.—Mesic areas, powerline, occasional. W&W 5080.

Cyperus strigosus L.—Mesic areas, powerline, occasional. W&W 6023.

Eleocharis ovata (Roth) Roemer & Schultes—Wet meadow, frequent. W&W 4925.

E. tenuis (Willd.) Schultes—Wet meadow, abundant. W&W 5029.

Scirpus atrovirens Willd.—Mesic openings, Pilot Knob trail, infrequent. W&W 5769.

S. cyperinus (L.) Kunth—Wet meadow, occasional. W,W&G 5280.

DIOSCOREACEAE

Dioscorea quaternata (Walter) J. F. Gmelin—Woods, Pilot Knob trail, occasional. W&W 5776.

D. villosa L.—Low woods along Brush Creek, frequent. W,W&G 5211.

IRIDACEAE

Iris cristata Aiton—Riparian woods, Brush Creek, frequent. W&W 4648.

Sisyrinchium angustifolium Miller—Wet meadow, low slopes, Kit Point, occasional. W&W 4907.

JUNCACEAE

Juncus acuminatus Michx.—Wet meadow, frequent. W&W 5039.

J. effusus L.—Wet meadow, frequent. W&W 5101.

J. marginatus Rostk.—Wet meadow, occasional. W&W 5037.

J. tenuis Willd. var. *tenuis*—Wet meadow, frequent. W&W 4977.

J. tenuis Willd. var *dudleyi* (Wieg.) F.J. Herm.—Wet meadow, infrequent. W&W 5025.

Luzula echinata (Small) F.J. Herm.—Low slopes, Kit Point, infrequent. W&W 4918.

L. multiflora (Retz.) Lej.—Rocky woods, Rotten Point, infrequent. W&W 6296.

LILIACEAE

**Allium vineale* L.—Naturalized. Wet meadow, ruderal areas, frequent. W&W 5023.

Disporum lanuginosum (Michx.) Nicholson—Rocky woods, Rotten Point, infrequent. W&W 5013.

**Hemerocallis fulva* (L.) L.—Naturalized. Old house site, Brush Creek, abundant. W&W 6893.

Hypoxis hirsuta (L.) Cov.—Wet meadow, abundant. W&W 4931.

Lilium canadense L.—Pilot Knob trailhead, rare. Observed only.

Medeola virginiana L.—Rocky woods, Rotten Point, infrequent. W&W 5009.

**Narcissus poeticus* L.—Naturalized. Old house site, Brush Creek, abundant. W&W 6951.

**N. pseudonarcissus* L.—Naturalized. Old house site, Brush Creek, abundant. W&W 6892.

**Ornithogalum umbellatum* L.—Naturalized. Old house site, Brush Creek, abundant. W&W 6894.

Polygonatum biflorum (Walter) Ell. var. *biflorum*—Riparian woods, Brush Creek, frequent. W&W 4657.

P. biflorum (Walter) Ell. var. *commutatum* (J. A. & J. H. Schultes) Morong—Woods edge, powerline right-of-way, occasional. W&W 5058.

Smilacina racemosa (L.) Desf.—Woods edge, Sage Point, frequent. W&W 5069.

Uvularia perfoliata L.—Riparian woods, Brush Creek, occasional. W&W 4658.

ORCHIDACEAE

Aplectrum hyemale (Muhl.) Torr.—Mesic woods, Millstone quarry trail, rare. Observed only.

Cypripedium acaule Aiton—Oak-pine woods, Kit Point, rare. Observed only.

C. calceolus L.—Mesic slopes, Pilot Knob, rare. Observed only.

Goodyera pubescens (Willd.) R. Br.—Wooded slopes, Pilot Knob, occasional. W 6732.

Hexalectris spicata (Walter) Barnhart—Rotten Point glade, rare. W 6669.

Liparis liliifolia (L.) Rich.—South slopes, Pilot Knob, rare. Observed only.

Malaxis unifolia Michx.—Oak-pine woods, bench above Brush Creek, rare. W&W 6623.

Tipularia discolor (Pursh) Nutt.—Oak-pine woods, Pilot Knob trail, occasional. W 6890.

POACEAE

Agrostis perennans (Walter) Tuckerman—Ruderal areas, Rotten Point, Pilot Knob, frequent. W&W 6010; W 6681.

Andropogon gerardii Vitman—Wet meadow, woodland glades, occasional. W&W 6030.

A. virginicus L.—Ruderal areas, powerline right-of-way, frequent. W&W 5545.

Brachyelytrum erectum (Schreber) P. Beauv.—Woods edge, wet meadow, Kit Point, infrequent. W&W 6858.

**Bromus commutatus* Schrader—Naturalized. Wet meadow, maintenance road, occasional. W&W 5089.

**B. inermis* Leysser—Naturalized. Wet meadow, maintenance road, occasional. W&W 4938X.

B. pubescens Muhl.—Wet meadow, maintenance road, occasional. W&W 6611.

**B. racemosus* L.—Naturalized. Rock outcrops, maintenance road, Rotten Point, occasional. W&W 5047.

Chasmanthium latifolium (Michx.) Yates—Wet meadow, woods edge, Sage Point, frequent. W,W&G 5224.

Cinna arundinacea L.—Mesic areas, Pilot Knob trail, occasional. W&W 6661.

**Dactylis glomerata* L.—Naturalized. Wet meadow, maintenance road, frequent. W&W 4927.

Danthonia spicata (L.) P. Beauv.—Ruderal areas, woodland openings, glades, frequent. W&W 5081.

**Digitaria ciliaris* (Retz.) Koeler—Wet meadow, maintenance road, abundant. W&W 6038.

**Echinochloa crusgalli* (L.) P. Beauv.—Naturalized. Disturbed areas, maintenance road, Rotten Point, occasional. W 6678.

E. muricata (P. Beauv.) Fern.—Wet meadow, maintenance road, frequent. W&W 6036, 6869.

**Eleusine indica* (L.) Gaertn.—Naturalized. Wet meadow, maintenance road, frequent. W&W 6064.

Elymus hystrix L.—Rocky woods, Rotten Point, occasional. W&W 5052.

E. virginicus L.—Low woods, Pilot Knob trailhead, infrequent. W 6746.

**Festuca arundinacea* Schreb.—Naturalized. Old house site, maintenance roads, frequent. W&W 6312; W 7453.

Glyceria striata (Lam.) A. Hitchc.—Wet meadow, Millstone quarry trail, frequent. W&W 4939, 5537, 6056.

Leersia virginica Willd.—Wet meadow, maintenance road, frequent. W&W 6001.

**Microstegium vimineum* (Trin.) A. Camus—Naturalized. Low woods, flood plain, Brush Creek, frequent. W&W 6574, 6886.

Muhlenbergia capillaris (Lam.) Trin.—Glade, Pilot Knob trail, infrequent. W 6704.

M. frondosa (Poiret) Fern.—Mesic areas, Pilot Knob trail, infrequent. W&W 6659.

M. sobolifera (Muhl.) Trin.—Woods margins, Millstone quarry trail, infrequent. W 6726.

M. sylvatica (Torr.) Torr.—Rock outcrops, Pilot Knob apex glade, occasional. W 6720.

Panicum anceps Michx.—Wet meadow, maintenance road, abundant. W,W&G 5245.

P. boscii Poiret—Grape Knob glade, powerline right-of-way, infrequent. W&W5071; W 7830X.

P. capillare L.—Rotten Point woodland glade, infrequent. W&W 7796.

P. clandestinum L.—Wet meadow, maintenance road, frequent. W&W 4973.

P. commutatum Schultes—Wet meadow, woods edge, Kit Point, occasional. W&W 4904.

P. dichotomiflorum Michx.—Wet meadow, maintenance road, frequent. W&W 5087.

P. dichotomum L.—Disturbed areas, wet meadow, maintenance road, Rotten Point, occasional. W&W 5034; W 6670.

P. lanuginosum Elliott—Wet meadow, maintenance road, occasional. W&W 6313.

P. linearifolium Scribn.—Ruderal areas, wet meadow, powerline, infrequent. W&W 5063.

P. microcarpon Muhl. ex Ell.—Low woods, Pilot Knob trail, occasional. W&W 5771.

P. polyanthes Schultes—Woodland glade, Rotten Point, occasional. W,W&G 5248; W&W 7797.

P. rigidulum Nees—Ruderal areas, wet meadow, powerline, infrequent. W 6685.

P. scoparium Lam.—Disturbed areas, wet meadow, frequent. W&W 6605.

P. sphaerocarpon Elliott—Mesic areas, Millstone quarry trail, occasional. W 7876.

Paspalum laeve Michx.—Wet meadow, maintenance road, infrequent. W&W 6874.

**Phleum pratense* L.—Naturalized. Wet meadow, maintenance road, frequent. W&W 6585.

**Poa annua* L.—Naturalized. Disturbed areas, Pilot Knob trail, infrequent. W&W 5534.

P. autumnalis Vahl—Open woods, Pilot Knob trail, occasional. W&W 4553.

**P. compressa* L.—Naturalized. Rocky woods, disturbed areas, Rotten Point, infrequent. W&W 6301.

P. cuspidata Nutt.—Riparian woods, flood plain, Brush Creek, occasional. W&W 4661.

Schizachyrium scoparium (Michx.) Nash—Wet meadow, woodland openings, glades, frequent. W&W 6031.

**Setaria faberi* R. Herrm.—Naturalized. Disturbed areas, maintenance road, Rotten Point, occasional. W 6675.

**S. glauca* (L.) P. Beauv.—Naturalized. Wet meadow, maintenance road, frequent. W,W&G 5232.

**S. viridis* (L.) P. Beauv.—Naturalized. Wet meadow, maintenance road, frequent. W&W 6042.

Sorghastrum nutans (L.) Nash—Glade, Pilot Knob trail, wet meadow, abundant. W 6700.

Tridens flavus (L.) A. Hitchc.—Wet meadow, maintenance road, frequent. W&W 6037; W 6690.

SMILACACEAE

Smilax bona-nox L.—Wooded slopes, Sage Point, infrequent. W&W 6613.

S. ecirrata (Engelm.) S. Wats.—Woods, Pilot Knob summit, infrequent. W&W 6652.

S. glauca Walter–Low slopes, Sage Point, frequent. W,W&G 5247.

S. hispida Muhl.—Open woods, Pilot Knob summit, infrequent. W&W 5765.

S. rotundifolia L.—Woods, throughout, abundant. W&W 5066.

TYPHACEAE

Typha latifolia L.—Blocked drainage, Brush Creek, infrequent. W&W 6248.

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Epipactis helleborine (Orchidaceae) in Kentucky, with Overview of Literature on Biology of the Species

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ABSTRACT

A status report on the introduced orchid *Epipactis helleborine,* helleborine, in Kentucky is presented. Literature on the plant—its dispersal, pollination, arthropod visitors, range, habitats, variation, cytology, hybridization, fungal symbiont, cultivation, medicinal uses, etymology, and nomenclature—is reviewed.

INTRODUCTION

The family Orchidaceae does not usually come to mind when one thinks of weedy plants, but there is one orchid that some describe as weedy or even invasive: *Epipactis helleborine* (L.) Crantz, helleborine (Figure 1). This Eurasian plant appeared in North America about 125 years ago and has since spread to six Canadian provinces and 28 U.S. states (plus District of Columbia) (Brown and Argus 2002; Kartesz and Meacham 1999). That it has recently been found in northern Kentucky piqued our interest; we thus decided to investigate the biology of the species as reported in the extensive literature on that topic. Our paper does not claim to be an exhaustive survey of that literature, but it may serve as a starting place for someone wishing to attempt the task. This paper, then, is concerned with much of what you wanted to know about *E. helleborine* but did not—until now—know where to look.

EPIPACTIS HELLEBORINE IN KENTUCKY

In July 1990 we were asked by a resident of rural Campbell County, Kentucky, to visit her garden to see a "strange flower" she had noticed among her marigolds and petunias but had not planted there. The plant was *Epipactis helleborine* (L.) Crantz, helleborine; we had seen it before in Illinois and Michigan. Photographs were made as a record of its occurrence. Two weeks later the plant's single stem, bearing old flowers but no developing fruits, was removed almost to ground level, presumably by a deer. And, later that summer, widening of the home's driveway covered the site of the orchid with asphalt.

In 1994, the species appeared in a garden in Alexandria, Campbell County, where it persisted three summers only, blooming in 1995 and 1996 but not reappearing in 1997, 1998, or 1999. But in 2000 and 2001 it appeared again at the same spot, blooming but not producing fruits each of the 2 years (voucher: *Thieret 60980,* KNK). The plant's underground parts may possibly have persisted during the 3-year hiatus (see "Fungal Symbiont" below). It did not reappear in 2002.

A third northern Kentucky site for helleborine was found by JWT in a cemetery in Southgate, Campbell County. At the edge of an open, rather weedy woods a single-stemmed helleborine plant (neither collected nor photographed) was past flowering in late August. It, too, showed no evidence of maturing fruits.

In 1986 *E. helleborine* was discovered "new" to Kentucky on Shipping Port Island in the Ohio River near Louisville, Jefferson County (Homoya 1993; B. Palmer-Ball pers. comm. 2003). It was this find that is the basis for the inclusion of *E. helleborine* in Medley's Kentucky checklist (Medley 1993). However, the voucher specimen (*Medley et al. 13508–85*), said to be deposited in the herbarium of the University of Louisville (DHL), is missing.

Figure 1. *Epipactis helleborine,* helleborine. Plant (center); two views of flower (left); flower, lateral view with one longitudinal half removed (lower right). From Correvon (1899).

Fernald (1946) remarked on this "sporadic appearance" of helleborine. Bentham (1878) noted about the species: "Not infrequent in Britain, but often appearing only in single specimens." This sporadic appearance—and reappearance—was investigated by Light and MacConnaill (1991) in a 5-year study of a population of ca. 760 individuals of helleborine in Quebec. They found that only ¼ to ½ of the plants came up in any given year, the rest remaining underground. Three of the plants came up after a 3-year hiatus. Only seven appeared above ground each of the 5 years.

In one season a plant may be tall and produce four or more leaves and 20 or more flowers per inflorescence. In the next season it may be much smaller and not flower at all (Light and MacDonaill 1990); these authors found, by examining underground parts in one population, that ca. 50% of the plants not emerging annually were still alive. Thus population size can vary from year to year as estimated by the number of aboveground plants.

In nature, helleborine occurs not only as isolated individuals (e.g., Harrison 1941; Upham 1942) but also as colonies varying from a few to hundreds of plants (Anonymous 1887; Brown 1996; Correll 1978; Day 1882; Pretz 1926).

Growth of helleborine starts in late spring. Flowering is in early summer to early fall, and fruits mature from August to November (Boesse 2000).

An especially fine illustration of *E. helleborine* is in Ross-Craig (1971).

BIOLOGY OF THE SPECIES

Dispersal: From There to Here

How *E. helleborine* was introduced into North America is unknown. Some authors (e.g., Case 1987; Luer 1975; Robinson and Fernald 1908; Soper and Murray 1985) suggested that its introduction may have been intentional for its alleged medicinal value (see "Medicinal Uses" below). Marie-Victorin (1919, 1964) wrote that the orchid's presence on Mount Royal at Montreal could be traced to its spread from abandoned herb gardens: "The gardens . . . usually contained the best drug plants in favor at the time. When cultivation [ceased] at that particular spot, the plants had very often gained a strong foothold and were able to persist for centuries. A striking example of this is the abundance of [*Epipactis*] *helleborine* . . . on Mount Royal . . . . " (see Brunton 1986). Accidental introduction could also have occurred by way of seeds in soil brought in with other plants (Case 1987; Luer 1975).

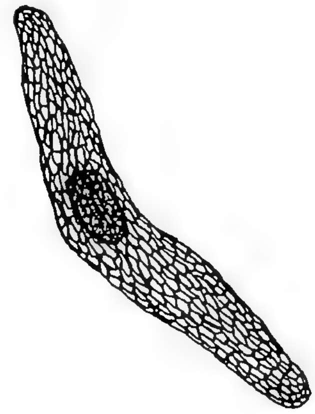

Figure 2. *Epipactis helleborine*, helleborine. Seed, showing the meshlike seed coat and the undifferentiated embryo. ×50. From Soper and Garay (1954).

The seeds of helleborine are minute (800–1100 μm long [Camus 1929; Richards and Porter 1982; Young 1962]), narrowly lanceolate (ca. six to seven times as long as wide), and without endosperm (Figure 2). They are said to be produced often "well in excess of 1000 per capsule" (Hollingsworth and Dickson 1997). Keenan (1998) noted, in a large population in Vermont, a "capsule success" rate of nearly 100% on several hundred robust individuals; all of the capsules had dehisced, revealing the whitish gray masses of seeds, an example of "extraordinary fecundity."

The seed coat is netted and loose, essentially an elongate mesh bag. Centrally located and occupying ca. ⅕ to ⅙ the length of the seed is the globose to ellipsoid, minute, undifferentiated embryo, essentially a cluster of a few cells. About 90% of the volume of each seed is airspace, allowing the seed to travel for long distances on air currents (Hollingsworth and Dickson 1997) or water (Rasmussen 1995).

Excellent scanning electron micrographs of seeds of helleborine were published by Arditti et al. (1980).

Dispersal of *E. helleborine* may be achieved in various ways. The exceedingly light seeds ("dust diaspores") are easily transported by wind or rainwash (the latter for at least short distances) or even a combination of the two

(Soper and Murray 1985). Ridley (1930) mentioned a Mr. Bree who, in England, wrote that "a seedling of this common English plant had appeared at a distance of between 8 and 9 miles from any place known to him [Bree] where it grew." "In Ontario, daughter colonies [thought to be from] the original station in Toronto have appeared at a distance of some ten miles [from it]" (Morris and Eames 1929). Dispersal in the fur of passing animals and in streams seems possible, too.

According to Rasmussen (1995), orchid seeds falling into water may remain afloat for weeks. The testa is covered with a water-repellent lipoid layer, and buoyancy is further improved by the rough sculpturing of the testa, which traps air bubbles, and by the air spaces between the capacious testa and the embryo.

Gardeners, too, assist in spread of the species, either through the transport of other plants bearing helleborine seeds incidentally or of actual helleborine plants or seeds. A Miss Schlegel, for example, distributed seeds and roots of helleborine to "many" gardeners and even to the U.S.D.A "for planting in their experiment stations" (White 1896). Zenkert (1930, 1949) mentioned the transport of roots from a colony of the orchid "to some outlying localities." Homoya (1993), noting that three of the four Indiana counties from which helleborine had been documented were in the Lake Michigan area, wrote that "there is strong evidence that Indiana populations are the progeny of an intentional planting and dispersal of seed that took place in 1895 in nearby Berrien County, Michigan . . . [helleborine] could have easily dispersed seed [from there to] our lakeshore area . . . ."

One of the first discovered North American stations for helleborine—in Buffalo, New York (Day 1882)—was on a hillside just below Forest Lawn Cemetery. Zenkert (1949) relocated the site in 1929; the orchid was still thriving there. He suggested that "seeds or sprouts of Helleborine chanced to have been intermingled with potted plants placed on [the] old burial plots [some dating back to 1871]. At the end of the growing season the steep hillside proved to be a very convenient place for dumping withered plant remains, together with the soil left in the flowerpots. In some such manner Helleborine evidently got its start on that hillside. The seed had come from Europe originally, imported by florists; for in those early days Helleborine was valued and grown in America for its reputed medicinal properties."

Soper and Murray (1985) suggested that transport of underground parts of helleborine might be brought about in nature by their being eroded from stream banks and carried downstream.

Whatever the means of dispersal, the movement of helleborine has been most impressive. In Pennsylvania, for example, the plant has spread from its first reported station in the state in 1906 (Pretz 1926) to about 80 sites in ca. 87 years (Rhoads and Klein 1993). Similarly, in New York, from which the species was first recorded in 1879 (the first North American record; Anonymous 1879; Gray 1879), ca. 65 localities were known by 1933 (House 1933). And in Ontario the orchid was known from 18 counties in 1948 (Montgomery 1948), after its original discovery in the province in 1890 (House 1933; Montgomery 1948). By 1974 it was said to be "very common in southern and eastern Ontario" (Greenwood 1974). Eleven years later (Soper and Murray 1985) the plant was known from "over 600" sites in that province. Voss (E. G. Voss pers. comm. 2003) described the spread of the plant in Michigan as "like wildfire." Harrison (1941) found helleborine "by the thousand" in a woodland near Pittsfield, Massachusetts. Fifty years after the plant's first discovery in Wisconsin—in a ravine in Milwaukee's Lake Park—Jorgensen (1982) visited the ravine and found the orchid still there; he counted 676 individual plants and suggested that the park's helleborine population might number "well into the thousands." Helleborine has thus become the commonest woodland orchid throughout much of its still-expanding North American range (Chapman 1997).

In Europe, too, helleborine can be a common orchid. Weijer (1952) remarked that it "grows in an enormous number on the island of Ameland", off the Netherlands coast.

Spread of the species could possibly be facilitated by the short time the plant takes to reach flowering stage from seed: 18 months, as reported by Coleman (1995). (Another author, though, suggested 8 years for this devel-

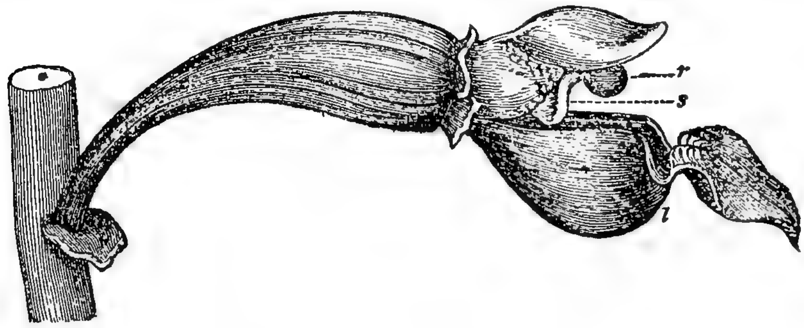

Figure 3. *Epipactis helleborine*, helleborine. Flower, lateral view with perianth removed. r = rostellum; s = stigma; l = lip. Note the hinged, distal part of the lip (epichile) and the cupped, proximal portion (hypochile). From Darwin (1877).

opment [Lang 1989]; further study is obviously needed).

Pollination: The Vespid Connection

The flowers of helleborine are pollinated primarily—or perhaps only—by social wasps foraging for nectar (Ehlers et al. 2002; Huxley 1978; Kerner von Marilaun 1895; Knuth 1909; Light 1994; Obi 2000; Sachs 1875; Strachan 2000; Ziegenspeck 1936). The insects involved are of the family Vespidae, primarily *Polistes* and *Vespula* in North America. In Europe "swarms of wasps" have been noted to frequent colonies of helleborine (Darwin 1877). It has even been suggested that "if wasps were to become extinct in any district [in England], so would the *Epipactis latifolia* [i.e., *E. helleborine*]" (Darwin 1869, 1877).

In orchids the usually one stamen is united with the style, forming a "column" or "gynostegium" that bears at its apex or laterally two pollinia, each a mass of coherent pollen grains transferred in toto during pollination. (Rasmussen [1982] wrote extensively about the morphology and development of gynostegia.) In out-crossing *E. helleborine* the pollinia and the stigma are separated by a barrier, the "rostellum," derived from a stigma lobe and tipped by a sticky layer, the viscidium, thus making self-pollination unlikely. The pollinia are attached to the rostellum, which detaches when the viscidium adheres to the head of a wasp as the insect visits the flower. Attachment is in such a position that the pollinia may contact and adhere to the stigma as the wasp visits the next flower (Huxley 1978; Kerner von Marilaun 1895).

The following account of pollination of helleborine is adapted from Huxley (1978) and Kerner von Marilaun (1895) (see also Gibson [1905], Judd [1972], and Proctor et al. [1996]). The wasp lands on the hinged, distal part (epichile) of the lip, bending it down, and crawls forward to sip nectar from the cupped, proximal part (hypochile), starting at the front end of the cup and moving toward the back (Figure 3). As the insect moves forward, its head contacts the stigma, to which adhere any pollinia it may be carrying. As it then tries to take off, the epichile springs up against its abdomen, forcing the insect upward in such a position that its head contacts and usually picks up the flower's pollinia (Figure 4). During the wasp's flight to another flower, the pollinia on its head tend to bend downward and are thus in a better position to contact the stigma of the next flower.

Somewhat at odds with the above description are the words of Darwin (1877): "The distal portion of the labellum . . . is firmly united to the basal portion . . . so that it is not flexible and elastic; it apparently serves only as a landing-place for insects. The fertilisation of this species depends simply on an insect striking in an upward and backward direction the highly-protuberant rostellum, which it would be apt to do when retreating from the flower after having sucked the copious nectar in the cup of the labellum."

Further study of pollination of helleborine seems called for.

Mousley (1927), in his observations on helleborine near Montreal, concluded that "it was seldom [that the wasps] went away without pollinia attached to their heads." With successive visits of several wasps to a single flower, three or four sets of pollinia can be deposited on the stigma (Mousley 1927).

Through frequent grooming by rubbing their legs over their head and thorax, the

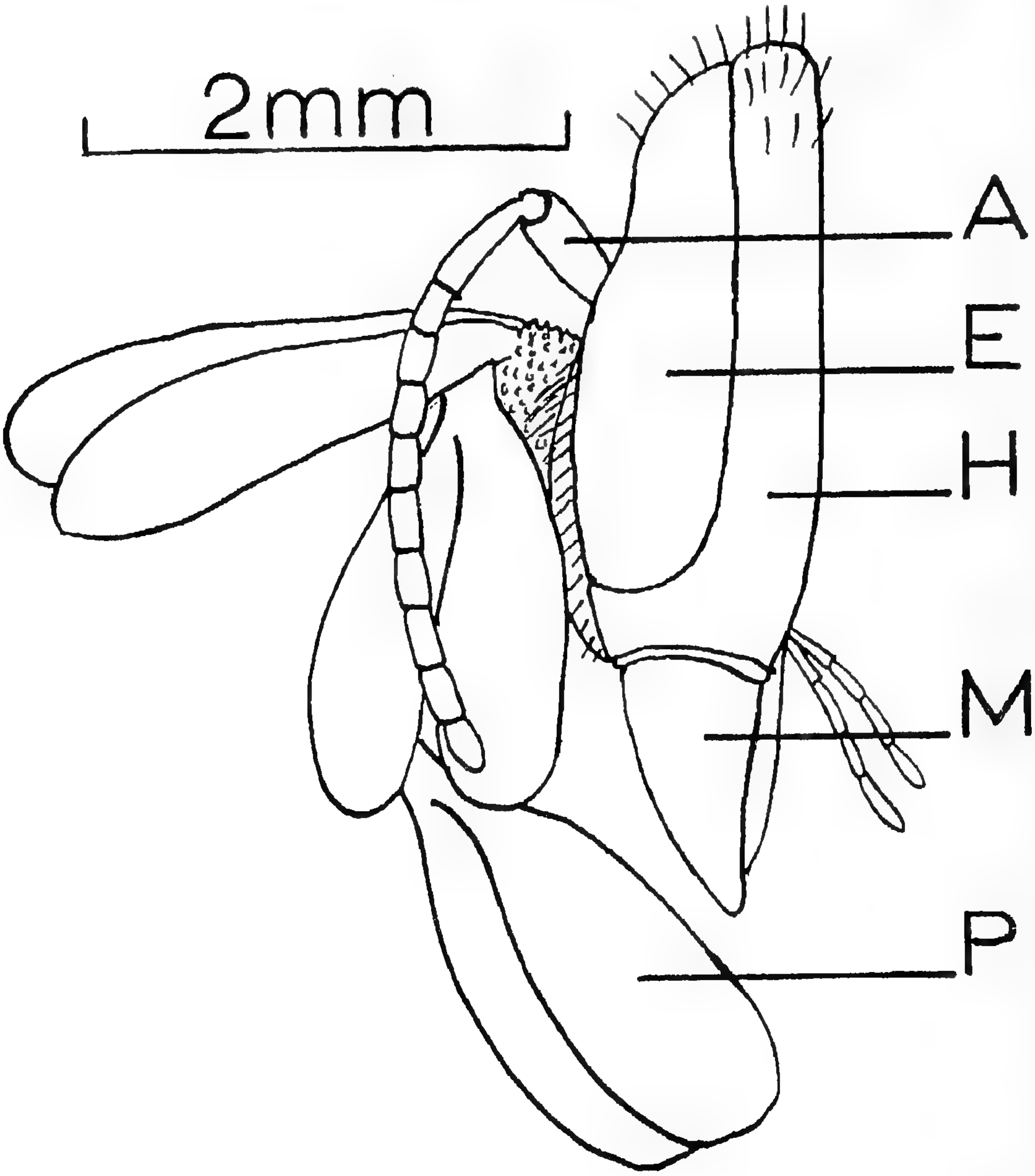

Figure 4. Lateral view of head of the wasp *Vespula vidua* bearing three pairs of pollinia of *Epipactis helleborine*. A, antenna; E, compound eye; H, head capsule; M, mandible; P, one of a pair of pollinia. From Judd (1972).

wasps may *remove* pollinia they have picked up, thus reducing their effectiveness as pollinators. There may, however, be "a solution to this problem." In Europe, Ehlers (2000) and Ehlers and Olesen (1997) found the nectar of helleborine to contain ethanol produced by fungi and bacteria; ethanol fumes are said to be attractive to wasps (Ehlers and Olesen 1997). As the insects visit the flowers and drink the spiked nectar, they may become "intoxicated." Once they have sipped some of the nectar, the frequency of grooming may decline, and thus they may visit the next flower with more pollinia on their head. According to Vandaveer (2002), "a tipsy wasp does not groom frequently and will visit the next flower with pollinia in place. It is theorized that this 'floral cocktail' improves the chances [that] the next flower gets cross-pollinated." Ehlers and Olesen (1997) found that the ethanol-producing micro-organisms were present also on wasps and on fruit from the surrounding vegetation on which the wasps were observed to forage. Thus the insects themselves may inoculate the nectar.

Judd (1979), observing a large group of helleborine in Ontario, noted no wasps visiting the flowers even though two active colonies of the wasp *Vespa* [i.e., *Vespula*] *arenaria* were within 700 feet of the orchids. Nonetheless, he concluded that "it is likely that [these wasps] were the pollinators, visiting the flowers at times when the plants were not being observed."

The aroma of the flowers of helleborine is said by some to be "pleasant" (Coleman 1995,

Figure 5. *Epipactis helleborine.* North American range of the species, each state or province of occurrence indicated by a dot (Montana not included because of questionable report from that state). Map prepared by Margaret Popovich, The Dawes Arboretum.

2002) or "subtle" (Burnie 1995); Camus (1929) compared it to that of valerian (*Valeriana officinalis*), the flowers of which have an odor reminiscent of vanilla (according to JWT). But of helleborine in Siberia Malyschev and Peschkova (2001) wrote that the flowers lack fragrance. Polunin (1969), too, described the flowers as "scentless." This difference in aroma may be one of the many ways in which the flowers are variable (see "Variants of Helleborine" below).

Various kinds of flowers reflect ultra-violet light, thus creating color patterns invisible to the human eye but detectable by insects, forming "guides" that help them locate nectar and pollen. Stigmas of helleborine are UV reflective before pollination. After pollination, the degree of reflectance diminishes until, within about 15 to 30 minutes, the stigmas are totally UV absorptive (Light 1994; Wespe 1997).

Although *E. helleborine* appears to be largely an out-crossing species, it is sometimes autogamous (e.g., Young 1953b), the autogamy being at times population specific. Although bagging experiments in Sweden showed no evidence of autogamy (Ehlers et al. 2002) in the studied populations, work at Brooklyn Botanic Garden concluded that the orchid does self-pollinate when there is a lack of insect activity as evidenced by the presence of pollinia still in place in those flowers that developed fruits (Obi 2000; Strachan 2000). Piper and Waite (1988) and Waite et al. (1991), too, noted fruit set in flowers that still retained their pollinia; the degree of autogamy was inversely proportional to the length of the inflorescence and the number of flowers per inflorescence. It should be noted, however, that self-pollination of helleborine cannot be assumed just because a flower's pollinia are still present in it; pollinating wasps *may* leave a flower *without* removing pollinia (Mousley 1927).

Facultative or obligate autogamous infraspecific taxa of helleborine are known in Europe, e.g., in some varieties in the Netherlands and Denmark (Ehlers et al. 2002; Pedersen and Ehlers 2000). Some species, too, in the *E. helleborine* complex (Novakova and Rydlo 1978; Pedersen and Ehlers 2000) are autogamous, some of them having been segregated from *E. helleborine* (Dahlgren et al. 1985). In autogamous helleborine the rostellum and viscidium are reduced or even lacking (Schulze 1894; Young 1953b). Mousley (1927) suggested the possibility of "self-fertilization" in cases where "the pollinia [of a flower] had twisted around from some cause or another, and had fallen over the top edge of the stigma, and on to the latter . . . ."

Other Arthropod Visitors to Helleborine

Bumble bees and various beetles may visit the flowers (Ehlers et al. 2002) as do hover flies (Squirrel et al. 2001). The flies and bumble bees were described as "nectar-robbers" by Ehlers and Olesen (1997), i.e., they visited the flowers for nectar but did not contact pollinia. These authors also observed beetles carrying pollinia randomly placed on the insects' bodies.

Honey bees have been noted to visit the flowers and, indeed, to have pollinia attached to their heads (Mousley 1927), but more often than not, the bees went away without pollinia. Whether the pollinia could be transferred to another flower is not known. Because the bees' proboscises are longer than those of wasps, the insects do not need to push so deeply into the flower to reach the nectar (Ehlers and Olesen 1997).

General notes on a variety of arthropods—mites, syrphid flies, thrips, aphids—visiting helleborine flowers in the Sudetic Mountains of Europe were published by Lingelsheim (1929). The seed capsules may be infested by larvae of the weevil *Stethobaris ovata* (Anonymous n.d. *Stethobaris*). *Stethobaris* adults chewed the flowers and destroyed them on many plants observed by Judd (1979); in one population noted by him, more than half of the plants were prevented from setting seed by activities of the weevil. Judd also recorded other arthropods crawling over the outside of the flowers: ants, bugs, halictid bees, harvestmen, lady beetles, spiders, and syrphid flies.

Helleborine flowers can be death traps for small insects: a fly observed by Darwin (1877) was "glued to the rostellum, and had there miserably perished." Judd (1972) found dead wasps in spider webs on the flowers.

For color photographs of insects visiting helleborine flowers see Guenther (2001b; wasp) and Squirrel et al. (2001; hover fly).

Range of *Epipactis helleborine*

North America. The introduced range of helleborine in North America, as given by Kartesz and Meacham (1999) and *Flora of North America* (Brown and Argus 2002) includes six Canadian provinces and 28 U.S. states (plus District of Columbia) (Figure 5). Dates and sources of significant reports of *E. helleborine* in Canada and the U.S. are given in Table 1.

Immediately after the initial North American discovery of *E. helleborine* (1879), Gray (1879) wrote that he had "no doubt that this [orchid] is truly indigenous in this only known North American station." Hooker (1879) apparently agreed, for he opined that the discovery "shows a connection between the American and European flora of the rarest kind." By 1890, though, Gray (1890) had concluded that the plant was introduced from Europe. That it was indeed an introduction was suggested by the fact that it would have been found prior to 1879, in a botanically well-explored region (House 1924; Pretz 1926). But some uncertainty persisted even as late as 1913 when Britton and Brown (1913) wrote "probably introduced."

The first appearance of the orchid in a North American flora was in the sixth edition of Gray's manual (Gray 1890): "near Syracuse and Buffalo, N.Y.; the only known stations [in the manual range]." The expanding range can be traced in later editions: "Que. and Ont. to Mass, N.Y., and Pa." (7th edition; Robinson and Fernald 1908); and "sw. Que. and Ont., s. locally to N.H. and w. N.E., N.J., Pa., D.C. and Mo." (8th edition; Fernald 1950). Much the same geographic data can be seen in successive editions of the Britton and Brown manual (Britton and Brown 1896, 1913; Gleason 1952).

Eurasia. In Eurasia the presumably native range of helleborine extends from the British Isles, western Europe, and northwestern Africa eastward in a broad band to Siberia, China, and Nepal (Luer 1975).

The Eurasiatic floras we have seen that document the presence of *E. helleborine* in the various geopolitical areas are as follows (in alphabetical order): AFGHANISTAN (Davis

1984); BHUTAN (Pearce and Cribb 2002); CAUCASIA (Davis 1984; Pearce and Cribb 2002); CHINA (much of China except some of the coastal provinces [Xinqi et al. n.d.]); CHUMBI (Pearce and Cribb 2002); CRIMEA (Townsend and Guest 1985); CYPRUS (Meikle 1985); DAHURIA (Pearce and Cribb 2002); EUROPE (all except Azores, Balearic Islands, Faeroes, Iceland, and Svalbard [(Moore 1980]); HIMALAYA (western [Murti 2001]); IRAN (north and northwest [Davis 1984]); IRAQ (Townsend and Guest 1985); KASHMIR (Hooker 1894); LEBANON (Townsend and Guest 1985); MYANMAR (Murti 2001); NEPAL (western and central [Hara et al. 1978]); PAKISTAN (Davis 1984); "PALESTINE" (Upper Galilee, Mt. Carmel, Samaria, Golan [Feinbrun-Dothan 1986]); RUSSIA (all except Far East [Czerepanov 1995]); SIBERIA (Malyschev and Peschkova 2001); SIKKIM (Hooker 1894; Pearce and Cribb 2002); SYRIA (western [Davis 1984]); TURKEY (Davis 1984); U.S.S.R. (European part, Caucasus, Siberia, central Asia [Komarov 1968; see RUSSIA above]).

Japan is problematical. Ohwi (1984) did not include *E. helleborine* in his *Flora of Japan.* But recently two of the taxa he *did* include have been transferred to varietal rank under *E. helleborine* (Royal Botanic Gardens 1998). Pending a revision of *Epipactis,* the presence of helleborine in Japan is uncertain.

The species occurs also in northwestern Africa (Algeria, Morocco [Townsend and Guest 1985]).

Maps of the range of *E. helleborine* in various geopolitical areas are in Tralau (1972).

Habitats

Many, perhaps most, species of temperate North American orchids are selective as to habitat, but not *E. helleborine,* which grows in places as disparate as the heart of some big cities (e.g., Glasgow; Dickson 1990) and old growth forests. Habitats we have seen listed for it include (in no particular order) beech, oak, or mixed woods; wooded hillsides; shaley ravines; dry rocky slopes; clayey loam; limestone substratum; black muck; aspen copse; sphagnum bogs; industrial spoil heaps; along railways; hard, barren clay; uncut lawn grass; gardens; thickets; railway embankments; annually flooded woodlands; gravel paths; and old graveyards. Many of these are sites under human influence, but the species also grows in areas seemingly far from such influence, e.g., in a virgin forest of white pine and hemlock at a Nature Conservancy site (Big Reed Pond) in northern Maine far from any settlement (except fishing camps) (H. Black pers. comm. 2003).

Boesse (2000) found the orchid in sites ranging from acidic to circumneutral, wet to dry, disturbed to undisturbed, and full sun to shade. Soil organic matter varied widely, as did calcium levels (no calcium detectable in one site). The plant appears to be a poor competitor, being noted often in areas with few or no competing plants. It responds positively to disturbance—as in flower beds, roadsides, and trail edges—perhaps because of increased light intensity (Stephenson and Stephenson 1921).

In North America the species occurs at elevations ranging from sea level (Brown and Argus 2002) to 5300 ft (1600 m) in New Mexico (Coleman 2002). In the Himalayas one form of *E. helleborine* is said to reach an elevation of 11,000 ft (Darnell 1930).

Luer (1972), speaking of orchids in general, wrote that "it is. . . easy to comprehend that the chance for survival of an orchid seed to grow to maturity approaches one in a million." Considering the rapidity of spread of *E. helleborine* in the New World, we suggest that the odds against it might not be so formidable as for some other orchids, probably because it is less selective when it comes to habitat.

Variants of Helleborine

An orchid "always interesting for its variations in [flower] color" (Smith 1989), *E. helleborine* is highly variable also in stature, leaf size and shape, density and shape of inflorescence, and floral morphology (Clapham et al. 1987). Helleborine is indeed a species characterized by high levels of polymorphism (Ehlers and Pedersen 2000). The characters mentioned can occur in "every possible cross-combination" (Stephenson and Stephenson 1921), producing plants "very unlike one another at first sight" (Summerhayes 1951). The value of these features in infraspecific classification was called into question by Stephenson and Stephenson (1920) who wrote that "it may or may not be possible to distinguish varieties within

Table 1. Dates and sources of significant reports/specimens known to us of *E. helleborine* in North America. State/province names followed by an asterisk indicate that the report is based on a herbarium specimen; the collector's name/collection number (if any) plus the herbarium acronym (following Holmgren et al. 1990) are given. Names in bold capitals indicate the earliest report/collection we have noted from each political area.

1870s

1879, **NEW YORK**: Syracuse (Anonymous 1879; Gray 1879)

1880s

1882, New York: Buffalo (Day 1882; Johnson 1926)
1887, **MASSACHUSETTS***: South Hadley (*Cook 4111*, AMES)
1888, New York: Onondago County (Peck 1890)

1890s

1890, **ONTARIO**: Toronto (House 1933; Soper and Garay 1954)
1892, **QUEBEC**: Montreal (Doyon and Cayouette 1966; Penhallow 1893)
1894, New York: Rochester (House 1933)
1896, New York: Canandaigua (Anonymous 1896)
1897, MASSACHUSETTS: Stockbridge (Hoffman 1899; Williams 1902)

1900s

1906, **PENNSYLVANIA**: Sayre (Pretz 1926)

1910s

1910, **NEW JERSEY**: Plainfield (Taylor 1910)
1915, **DISTRICT OF COLUMBIA**: Soldiers Home woods (Reed 1964)
1917, New York: Cayuga County (Metcalf and Griscom 1917)
1919, **MICHIGAN**: Niles (Drew and Giles 1951; Fuller 1933)

1920s

1925, **VERMONT**: Hartland (*Hazen s.n.*, Hartland, AMES; Webster 1926
1926, Pennsylvania; Bucks County (Pretz 1926)
1928, **MISSOURI**: Jasper County (Schweinfurth 1940)
1928, **WISCONSIN**: Ozaukee (Throne 1931)

1930s

1930, New York: Buffalo (Zenkert 1930)
1930, Wisconsin: Milwaukee (Fuller 1933; Throne 1931)
1930, **INDIANA**: Laporte County (Deam 1940; Nieuwland and Just 1930)
1931, **CONNECTICUT**: West Hartford (Upham 1942)

1940s

1940, Michigan: Michigan State University (Voss 1965)
1940, **MONTANA**: Helena (Schweinfurth 1940) (Dubious report)[1]
1941, Massachusetts: Mt. Greylock (Harrison 1941)
1942, **NEW HAMPSHIRE**: Plainfield (Upham 1942)
1947, New Hampshire: Meredith (Titherington 1947)

1950s

1950, **CALIFORNIA**: San Mateo County (Howell 1966; McClintock 1975)
1954, **ILLINOIS**: Barrington (Mohlenbrock 1970: Steyermark 1955)
1956, Michigan: Elberta (Voss 1965)
1958, **OHIO**: Summit County (Braun 1967)

1960s

1960, **MAINE**: Sebasticook River (Brower 1960)
1960, Michigan: Porcupine Mountains (Voss 1965)
1966, **NEW BRUNSWICK***: Carleton County (*Roberts 66–760*, UNB)
1969, **NORTH CAROLINA***: Macon County (*Sargent 2*, UNC)
1969, **WEST VIRGINIA***: Preston County (*Hutton s.n.*, WVA)

1970s

1975, **VIRGINIA***: Rockingham County (*Roe 1139*, WILLI)
1976, **ARKANSAS***: Washington County (*Moore s.n.*, UARK)

Table 1. Continued.

1980s

1982, **RHODE ISLAND***: South Kingstown (*Tucker 1787a*, GH)
1983, **BRITISH COLUMBIA***: Vancouver (*Straley 2832*, UBC)
1984, **MARYLAND**: Baltimore City (Brown and Brown 1984)
1985, **NOVA SCOTIA***: Blomidon Provincial Park (*Forsythe and Newell*, ACAD)
1985, **OREGON***: Jackson County (*Lang 1564*, ORE, SOC)
1986, **KENTUCKY**: Jefferson County (Homoya 1993)

1990s

1993, **MINNESOTA***: Winona County (*Nation 1227*, MIN)
1993, **NEW MEXICO**: Albuquerque (Sivinski 1993)
1993, **TENNESSEE**: Sevier County (Chester et al. 1993)
1994, **COLORADO***: Boulder (*Shawver s.n.*, COLO)
1995, **NEWFOUNDLAND***: St. John's (*Clase 1291*, NFM)

[1] Helleborine was recorded as "new" to Montana by Schweinfurth (1940) on the basis of a collection with skeletal data ("Helena, *F.W. Anderson s.n.*") in the herbarium of Oberlin College, a herbarium since transferred to Miami University (MU). Dr. M. A. Vincent, director of MU, located the voucher and provided some data on F. W. Anderson (1866–1891), who lived in Montana from 1883 to 1888 (or perhaps 1890). Thus Anderson's specimen may have been collected in the 1880s, assuming no mix-up in data. Helleborine might have been cultivated on the frontier in Montana that early for medicinal use, but we remain skeptical of the collection data. We checked—in vain—MONT and MONTU for Montana collections of helleborine. Probably on the basis of Schweinfurth's report, helleborine is included in Dorn's *Vascular plants of Montana* (Dorn 1984) as occurring in Lewis and Clark County, the location of Helena. We await verification of the presence of helleborine in Montana.

[*E. helleborine*]." In a similar vein Camus (1929) remarked, "Plante polymorphe dont les différentes formes n'ont pas toujours l'importance qu'on leur a attribuée."

Recognizing this variation, Nevskii (1986) wrote that "it should, however, be pointed out that *Epipactis latifolia* [i.e., *E. helleborine*] on USSR territory does not make the impression of a homogeneous entity . . . ."

Variations in flower color are "extensive and striking" (Brown and Argus 2002). In "one wood" alone, Webster (1886) found "all gradations of colour, from pure white, through the normal green, to . . . deep pinky purple." Brown and Argus (2002) noted forms that are white flowered, forma *alba* (Webster) Mousley (Mousley 1927); yellow flowered, forma *luteola* P.M. Brown (Brown 1996); albino, forma *monotropoides* Mousley (Mousley 1927); and green flowered, forma *viridens* A. Gray (Brown 1996).

The variation shown by helleborine has led to the description of several infraspecific taxa, many of them in the rank of form. Irmisch (1842) early listed four forms based on features of leaves, color of flowers, and nature of the tubercles on the lip. A summary of all forms described to the 1930s was published by Krösche (Hegi 1939). In North America, Mousley (1927) recognized four forms in the Montreal area, including the aptly named f. *monotropoides* for the albino ("snow-white") plant. It is the albino to which the epithet *albina*, as a form, was later proposed by Müller (1946) in Denmark.

Helleborine can be a stately plant indeed. In Quebec, Mousley (1927) found a plant 108.35 cm tall, taller than any other New World report known to him. Gupton and Swope (1986) had 1.2 m as the maximum in the middle Atlantic states. These data, however, were far surpassed by the maximum of 5 feet (= 1.61 m) of Summerhayes (1951). In central Europe, (18–)20–50(–90) cm was given by Hegi (1939) as the range in height.

Mousley (1927) gave the following data for helleborine as seen by him at Montreal: average height 51 cm, average length of raceme 12.5 cm (maximum 43.5 cm), and average number of flowers or capsules per raceme 26 (maximum 92).

Chlorophyll-free mutants of helleborine are known to occur widely in Europe, e.g., in Finland, where they were described as being "abundant" (Salmia 1986), Belgium (Delforge 1998), Denmark (Müller 1946), Germany (Jaedicke 1970; Renner 1938), Norway (Jørgensen 1993), and Switzerland (Salmia 1986). In North America they have been noted in California (Coleman 1989, 1995), Illinois (Case 1987), Ontario (Montgomery 1948), Quebec (Mousley 1927), and Wisconsin (Jorgensen 1982). Such albinos may persist underground for years as a colorless "mycorrhizome," eventually reaching the flowering stage. Coleman (1989) noted that the white plants, as observed by him among plants of the "standard" green form in California, "were normal in size and shape, but entirely white; there was not a trace of chlorophyll visible . . . the white plants seemed to represent about 10% of the population. Portions of old stems around the new stalks indicated the white plants had returned for several years. Some of the white plants were of flowering size, and one had swelling buds, though none were open." In Finland, Salmia (1986) reported that the albino plants flower and fruit normally, though at a lower rate than do green plants, and that white plants can survive underground for 1 or more years before reappearing. Albino plants may produce red flowers, which gives a striking effect (Withner 1959).

As do other forms of helleborine, the chlorophyll-free mutants occur in association with a symbiotic fungus (Salmia 1986) (see "Fungal Symbiont" below). In asymbiotic germination, albino plants quickly died once they were transferred from the culture medium to soil. The culture medium, by providing needed nutrients, had allowed the seedlings to grow (Griesbach 1979).

In a mixed population of green and albino individuals of helleborine, the number of albinos declined during a succession of dry summers, suggesting that the albinos are less robust than the greens, hardly a startling conclusion (Rasmussen 1995).

Other aberrant color forms of helleborine are those with chlorotic, yellowish green leaves and those with variegated leaves (Salmia 1986).

Frequently present at the base of the inflorescence of helleborine are a few flowerless bracts. Butzin (1983) discussed these but came to no conclusion as to why there are no flowers in the axils.

Peloric flowers may occur in helleborine (Camus 1929; Irmisch 1842).

Cytology

The chromosome counts we have seen for *E. helleborine* are 2n = 38, 39, 40 (Hess et al. 1967; Meili-Frei 1966); 2n = 36, 44 (Hollingsworth and Dickson 1997); 2n = 38 (Gadella and Kliphuis 1963); and 2n = 36, 38, 40, 44 (Brown and Argus 2002; Young 1953a). Clapham et al. (1987) reported the count as "2n = 40, with aneuploid variants." Chromosomal irregularities in the species were discussed by Meile-Frei (1966). Helleborine has both diploid and tetraploid races in parts of Europe; crosses between these races can produce triploids and aneuploids (Withner 1959).

Hybridization

A list of hybrids of European orchids, including *E. helleborine,* is given in Guenther (2001a). In Britain, *E. helleborine* is said to hybridize with *E. atrorubens, E. purpurata,* and possibly *E. leptochila* (Lang 1989).

Fungal Symbiont

The seeds of helleborine must be carried into a favorable environment and also apparently must rely on a symbiotic association with a fungus to supply them with enzymes and nutrients needed for germination. The fungal symbiont of helleborine was investigated by Boesse (2000). Her experimental work indicated that the fungus is instrumental in nutrient assimilation by the plant; the fungus possibly is able to extract nutrients tightly bound to large organic molecules. This relationship with the fungus may allow helleborine to develop in habitats that are otherwise inimical to the plant's success, e.g., areas with inadequate nutrients, low light intensity, poor soils, and insufficient moisture.

That the species can "probably persist in a non-flowering underground state for many years without producing the flowering stems" by relying, for its nutrition, on on the symbiotic fungus in its roots was suggested by Anonymous (n.d. *Epipactis*); 3 years of a subterranean life was the maximum confirmed by Rasmussen (1995).

The symbiotic fungus has been cultured from both green and albino plants of *E. helleborine* in Finland (Rasmussen 1995). In culture it is slow growing, the mycelium turning brown when mature. The hyphae, thick-walled and verrucose, possess intercalary monilioid cells. It does not appear to be a member of *Rhizoctonia,* a genus that occurs in at least some other species of *Epipactis.*

Cultivation

Although *E. helleborine* is included in various garden dictionaries and encyclopedias (e.g., Everett 1981; Miller 1764; Nicholson

1885; Paxton 1868; Woods 1984) the plant is not a favorite among gardeners.

According to Cribb et al. (1995), most species of *Epipactis*—at least those of Europe, including *E. helleborine*—are of little garden interest, only *E. palustris* being "arguably at all showy." Of the others, *E. helleborine* "is not uncommonly found in gardens and under old hedgerows in suburban areas [in the British Isles] . . . the plant is common in gardens in Glasgow and Belfast but its greenish or less commonly purplish flowers in mid-summer are often overlooked." Darnell (1930) described the plant as being "of but little garden value." The flowers of helleborine "cannot be called striking or beautiful. Compared with the 'Dragon's Mouth' or the 'Grass Pink,' the Helleborine is as homely as a Figwort [*Scrophularia*] among Foxgloves [*Digitalis*]" (Morris and Eames 1929). "Any plant with such small dull flowers is not likely to be a much sought after ornamental" (McClintock 1975). On a slightly positive note, the foliage of *E. helleborine* is attractive, reminiscent of *Cypripedium* leaves (Chambers et al. 1996), and its flowers are "structurally interesting" (Homoya 1993; Keenan 1998). The white-flowered form, which is "extremely handsome," was extolled by Webster (1886) as a plant of "great interest and of the easiest culture."

At times helleborine is considered a garden weed and efforts are made to get rid of it (Pretz 1926). Brenan (1983) noted that, in California, the plant was a "troublesome and spreading weed in garden beds, a very unfamiliar role for a plant so modest in its behaviour in Britain." It is listed as one of the "lawn and garden weeds" in Ontario (Alex et al. 1982); Sanders (1978) noted a helleborine plant "in a lawn [at Cornell University, Ithaca, New York] . . . in full sun, where it frequently gets stepped on and is mowed down once a week in the summer." Helleborine has even been called an "insidious" weed that should be eliminated from the Canadian flora (Dore 1968, 1977; Soper and Murray 1985); Weber (1970) referred to it as "une mauvaise herbe." For the record, each of us would *welcome* the plant in his garden.

Experimental work in Europe has shown that a helleborine agglutinin has "great potential" as a biopesticide (against insects and nematodes) (Peumans 2001).

Medicinal Uses

At one time helleborine was used in Europe and North America in folk medicine (Case 1987; Marie-Victorin 1919). Apparently that use has tapered off except perhaps in remote districts. Underground parts of the plant were used to treat arthritic pain (LeMaout and Decaisne 1876), gout (Bois 1893), and swelling and inflammation of the joints (Castle 1886; Emboden 1974), though with what results seems unrecorded. Duchesne (1836) mentioned the plant's use as a vulnerary and detersive but gave no details. Remarkably, it was also used to "cure" insanity (Bhattacharjee 1998). According to Gerard (1633), "It is reported that the decoction of wilde hellebore [i.e., helleborine] drunken, openeth the stoppings of the liver, and helpeth any imperfections of the same."

Etymology

The generic name *Epipactis* is a classical name used by Theophrastus for a plant of uncertain identity but possibly applying to plants of the genus *Helleborus* of the Ranunculaceae, to which *E. helleborine* bears but a vague resemblance (both are green). The specific epithet *helleborine* has the same derivation (Correll 1978; Quattrocchi 2000; Schultes and Pease 1963).

According to Hooper (1817), "epipactis" is a "plant mentioned by Dioscorides and so named because its juice was said to curdle milk." The name was said by Paxton (1868), Plowden (1969), and Shosteck (1974) to derive from the Greek *epignuo* or *epipegnus,* to coagulate. Plowden even stated that the plant was used in cheese making in Britain, an assertion we have been unable to verify.

The name "epipactis" was indeed used by Dioscorides but perhaps not for this species. Osbaldeston and Wood (2000) showed a picture of *E. helleborine* next to a paragraph from Dioscorides' *De materia medica* that they considered as descriptive of that species, but the paragraph in no way applies to helleborine.

Some authors (e.g., Macleod 1952) stated that the common name helleborine derives from the resemblance of the leaves of helleborine to those of *Helleborus.* These authors apparently have never seen *Helleborus,* the digitately or pedately divided leaves of which bear little resemblance to those of helleborine. Luer (1975) suggested that helleborine "recalls the hellebore more by its ancient uses than by its appearance . . . ." A reasonable explanation of the origin of the name is that the plant was so-named because its leaves resemble those of *Veratrum*, which has been called hellebore since ancient times (Alcock 1876; Gerard 1633; Grigson 1974; Prior 1870).

Gerard (1633), referring to "Wilde white Hellebor" [i.e., helleborine], wrote that "Helleborine is like unto white Hellebor [*Veratrum*], and for that cause we have given it the name of *Helleborine*. It hath a straight stalk of a foot high, set from the bottome to the tuft of floures, with faire leaves, ribbed and chamfered like those of white Hellebor, but nothing neere so large, of a darke greene colour . . . . The likenesse that it hath with white Hellebor, doth shew it may not improperly bee named *Helleborine*, or wilde white Hellebor, which is also called of *Dioscorides* and *Pliny* . . . *Epipactis*; But from whence that name came it is not apparant."

Nomenclature

Helleborine was originally described by Linnaeus in 1753 (Sp. Pl. 2:949) as *Serapias helleborine*, a name used by some authors until well into the 20th century. The generic name *Epipactis* was published by Zinn in 1757 (Cat. Pl. Hort. Gott. 85); Crantz made the combination *Epipactis helleborine* in 1769 (Stirp. Austr. Fasc. ed. 2, 2:467).

Epipactis helleborine has been known by an assortment of scientific names (Anonymous 1997; Morong 1893). In North American literature it has been reported under four binomials in addition to *E. helleborine*: *Amesia latifolia* (Mousley 1927; Throne 1931); *Epipactis latifolia* (Anonymous 1887; Upham 1942); *E. viridiflora* (Anonymous 1896; Morong 1893); and *Serapias helleborine* (Britton and Brown 1913; Harrison 1941; Robinson and Fernald 1908).

A comparison of infraspecific taxa of *E. helleborine* listed for Europe or parts thereof shows the nomenclatural confusion that exists for this species. Camus (1929) recorded 13 infraspecific taxa for "Europe." For "Mittel-europa" Hegi (1939) listed eight infraspecific taxa, only three of which are in Camus's list. And later, for the Netherlands, Vermeulen (1958) accounted for 12 such taxa; only two of these appear in Camus.

To add to the nomenclatorial tangle, the name *Epipactis* has been used for the rattlesnake-plantains, those orchids now known as *Goodyera* (e.g., Chapman 1997; Robinson and Fernald 1908), and for some species now included in *Listera* (Bigelow 1840).

The English common names we have noted for *E. helleborine* are Oakes Ames' orchid, bastard helleborine, broad-leaved helleborine, broad-leaved epipactis, weed-orchid, broad-leaved orchid, hellebore, helleborine, and helleborine orchid. For the unfortunate name "sauce-box"—probably an allusion to the nectar-containing pouch on the proximal portion of the lip—we are indebted to Morris and Eames (1929).

EPIPACTIS: THE GENUS

Epipactis, a "very imperfectly understood" genus (Clapham et al. 1987), includes some 24–30 species distributed over the northern hemisphere; most are Eurasiatic, but one extends south to Mozambique (Dahlgren et al. 1985; Stewart and Griffiths 1995). Many of the species are "scantily delineated, with the result that the genus is in a state of considerable taxonomic confusion" (Hawkes 1965). Moore (1980) wrote of *Epipactis*: "A difficult genus, particularly with regard to those species . . . which are largely or entirely autogamous."

A review of literature on *Epipactis*, especially its nomenclature, is given by Nannfeldt (1946).

Anyone working with *Epipactis* should heed the advice of Stephenson and Stephenson (1920): "Nothing can be done with the genus *Epipactis* from pressed plants . . . fresh material is essential." They urged preservation in alcohol of some flowers of each collection. Study of *Epipactis*, including helleborine and using modern techniques, is much needed. The paper by Tyteca and Dufrêne (1994) is a good example of the application of some of these techniques to the study of the *E. helleborine* complex.

In addition to the introduced *E. helleborine*, two other species of the genus *Epipactis* are known from North America. Of these, *E. gigantea* is a wide-ranging native plant of western North America. A European species, *E. atrorubens*, has been reported from a serpentine quarry in northern Vermont (Brown 1997) and, earlier, on limestone in Quebec (Mousley 1927).

The three species of *Epipactis* in North America can be separated by the following key:

1. Lip 3-lobed; sepals 1.5–2 cm long .... *E. gigantea*
1. Lip not 3-lobed; sepals 0.6–1.4 cm long.
   2. Ovary densely pubescent; leaves in 2 opposite rows............ *E. atrorubens*
   2. Ovary glabrous to sparsely pubescent; leaves spirally arranged.. *E. helleborine*

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Vascular Flora of Feltner Lake, Laurel County, Kentucky

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ABSTRACT

The vascular flora of Feltner Lake and its contiguous habitats in Laurel County, Kentucky, was surveyed from 1999 to 2002. Three hundred fifty-one species in 221 genera and 88 families were documented from a 16-ha upland forested area in the Northern Cumberland Plateau. Forty-two (11.97%) were exotics. Plants consisted of Lycopodiophyta (4), Polypodiophyta (13), Pinophyta (3), and Magnoliophyta (331). The largest families in species richness were Asteraceae (44), Poaceae (37), and Cyperaceae (29). The annotated catalogue has vernacular name, relative abundance value, habitat(s), wetland status, and voucher number for each taxon. *Aconitum uncinatum,* a threatened plant species in Kentucky, was present. Six wetland and two nonwetland habitats are discussed with regard to their characteristic species and wetland indicator status. An oak swamp woods is an unusual habitat remnant for the southwestern region of eastern Kentucky.

INTRODUCTION

This floristic study is a continuing documentation of the flora and vegetation of Laurel County in the southwestern region of eastern Kentucky (Figure 1). Recent floristic studies in Laurel County included the flora and vegetation of a coal surface-mined area (Thompson et al. 1984); the flora of Rock Creek Research Natural Area (Thompson et al. 2000); the woody plants of Rock Creek Research Natural Area and watershed uplands (Thompson and Jones 2001); and new Kentucky plant state records (Abbott et al. 2001). Previous vegetational studies in Laurel County were made by Braun (1937, 1950).

The upland mixed mesic forested terrain in this portion of Laurel County is unique in having small remnants of oak swamp forest, which are rarely found in eastern Kentucky. Braun (1937) described the flora and vegetation of a swamp forest and wet meadow located a few kilometers southeast of the present study site. Studies of upland swamp forests in eastern and south-central Kentucky have been few (Braun 1950; Bryant 1978; Hannan and Lassetter 1982; Meijer et al. 1981).

In 1956, a 74-ha tract near London, in Laurel County, Kentucky, was leased from Levi Jackson Wilderness Road State Park by the University of Kentucky to establish a memorial site to J. M. Feltner, a University of Kentucky 4-H Cooperative Extension leader in Laurel County. This site, J. M. Feltner Memorial 4-H Camp, was dedicated in 1960 and came under the management of the University of Kentucky. In 1964, Feltner Lake, a 2.7 ha lake, was created for recreational purposes by constructing an earthen dam across an intermittent creek.

The vascular plants of Feltner Lake and the selected contiguous 13.3 ha of upland terrain were the focus of this study. Objectives were to (1) document the flora with representative vouchers, (2) compile an annotated plant list, (3) determine the wetland indicator status of each taxon, and (4) describe the plant habitats.

THE STUDY AREA

The J. M. Feltner Memorial 4-H Camp (hereafter Camp Feltner) is located just off KY 229 ca. 2.5 km south of London, the county seat of Laurel County. Feltner Lake lies at latitude 37°04′40″ N, and longitude 84°02′20″ W in the northeast part of the 7.5-minute series Lily Quadrangle (Figure 1). This part of Laurel County is located in the the Low Hills Belt Subsection, Northern Cumberland Plateau of the Eastern Broadleaf Forest Province (Keys et al. 1995), or the Cumberland Plateau of the Southwestern Applachians (Woods et al. 2002). The upland terrain has relatively slight differences in overall relief with slopes of 0–6%. The elevation of Camp Feltner ranges from 340 m to 380 m and is very level compared to most of the Low Hills Belt Physiographic Region. The elevation of Feltner Lake is ca. 346 m and the contiguous habitats vary from 353 m west of the lake to 340 m below the dam spillway.

The vegetation of Laurel County lies entirely within the Mixed Mesophytic Forest Region

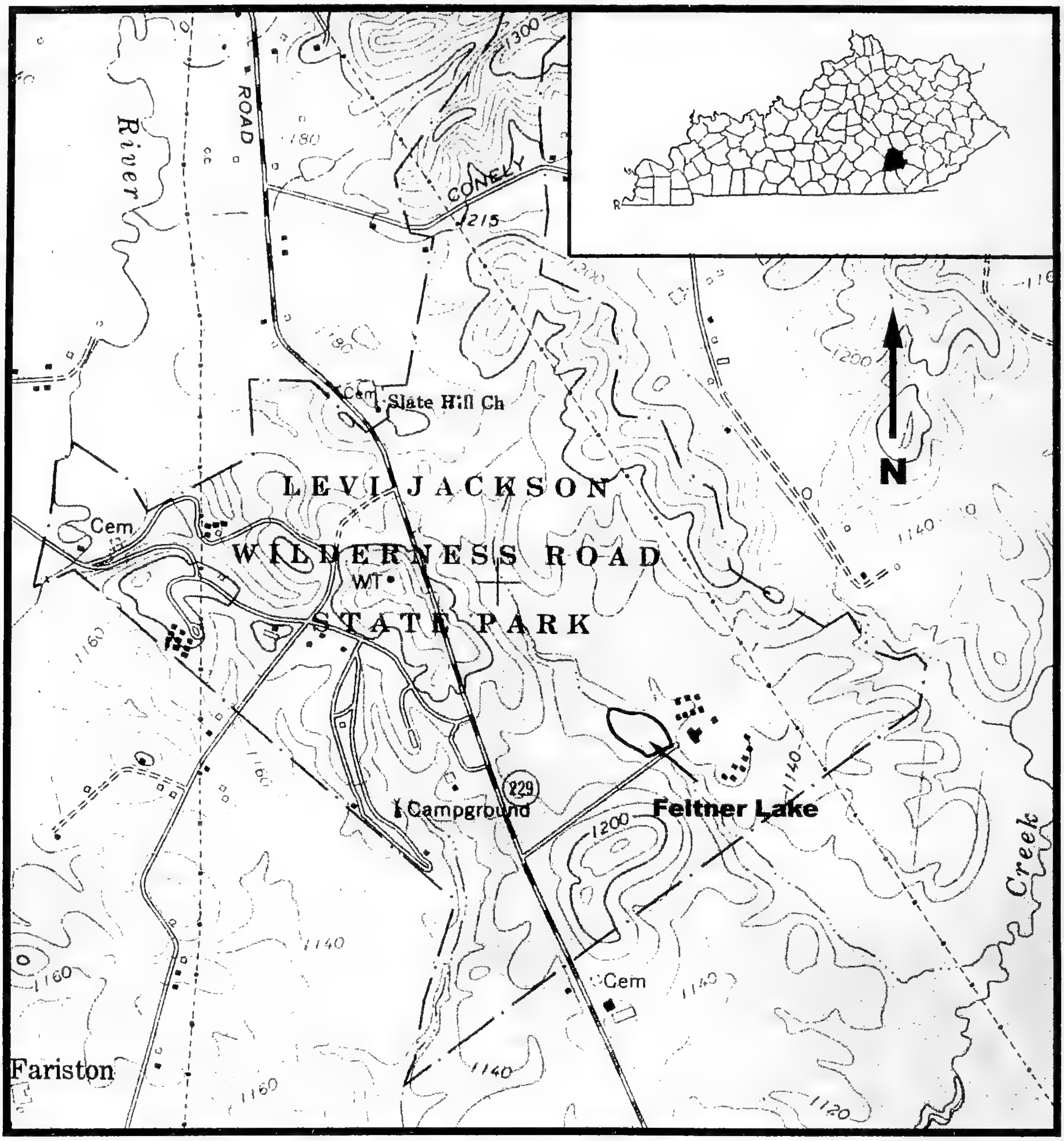

Figure 1. J. M. Feltner Memorial 4-H Camp environs and Feltner Lake, Laurel County, Kentucky. Modified from Lily Quadrangle, Kentucky, 7–5-minute series, U.S. Geological Survey, 1970.

of Braun (1950). Upland mesic oak forest comprises the majority of the forest vegetation of Camp Feltner, and this forest type forms a wide band surrounding Feltner Lake and its habitats. A 6.1-ha narrow band of this mesic oak forest was inventoried where it adjoined the 4.2-ha stand of oak swamp woods on the north, northwest, and west sides of Feltner Lake (Figure 2). Bedrock consists of very fine to coarse-grained pink- to yellow-brown sandstones of the Breathitt Formation of the Middle Pennsylvanian Series (Stager 1963). Stendal Silty Loams, the only soil series at Camp Feltner, are deep, poorly drained soils formed in loamy alluvium underlain by sandstones on nearly flat (0–4% slopes) floodplains and bottomlands. Effective rooting depth is limited by the seasonally high water table, especially during winter and spring. Thickness of the solum ranges from 76 to 102 cm. The dark grayish brown A horizon ranges to 15 cm and is acid to strongly acid (5.1–6.2 pH). The

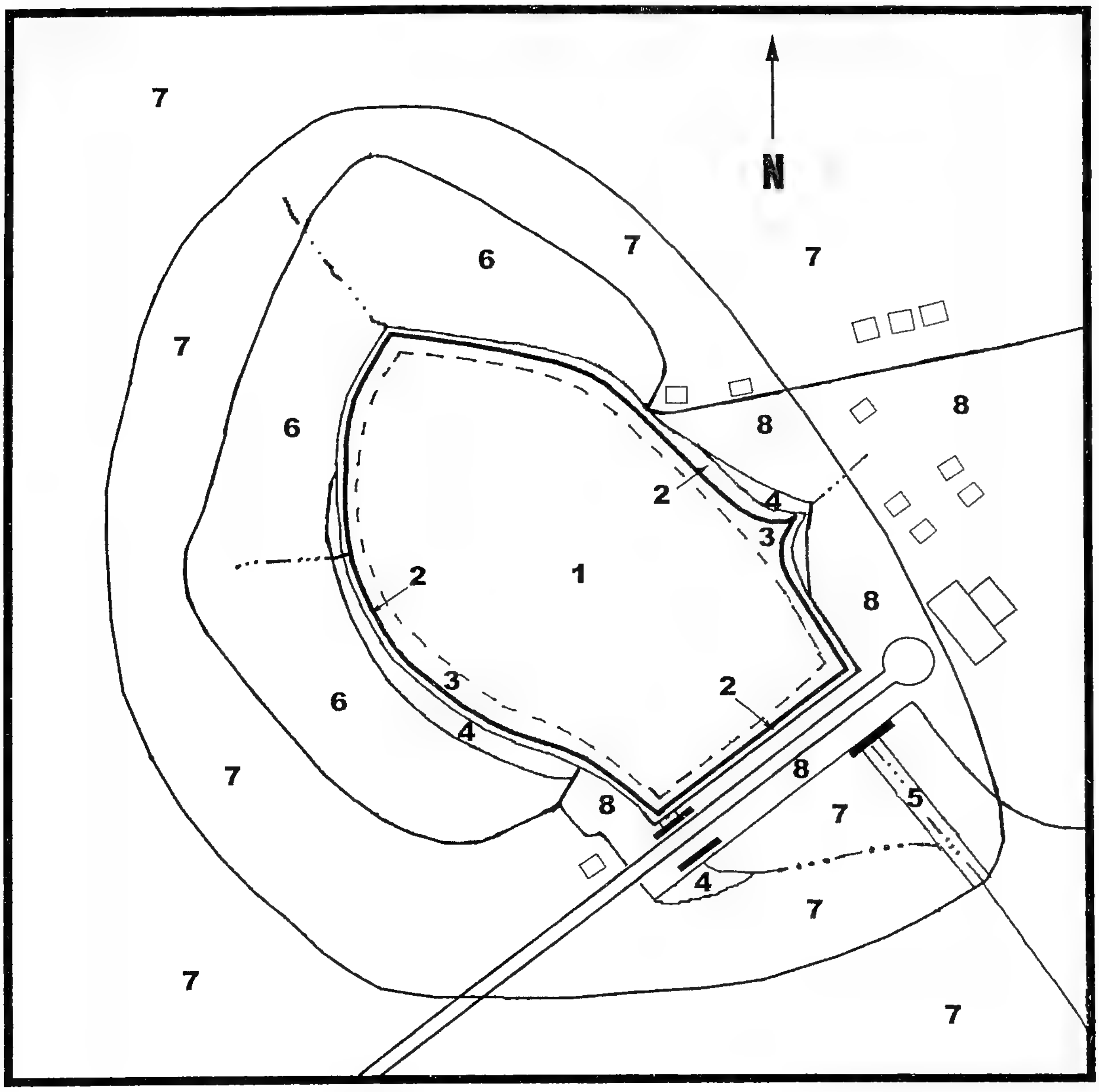

Figure 2. The eight habitats of Camp Feltner Lake and environs, Laurel County, Kentucky (map not to scale). 1 = Vegetated open water (VOW); 2 = emergent marsh (EM); 3 = seasonally dewatered mudflat (SDF); 4 = sedge-grass meadow (SGM); 5 = gravelly creekbank (GC); 6 = oak swamp woods (OSW); 7 = mesic oak forest (MF); and 8 = culturally derived habitat (CD).

light gray, silty loam B horizon varies from 15 to 102 cm and is very strongly acid (4.5–5.0 pH). Depth to sandstone bedrock is more than 1.5 m (Ross et al. 1981).

Climate of this area is classified as temperate humid continental with warm summers and cool winters and without a distinct dry season (Trewartha 1968). Climatic data from London gave a mean annual temperature of 13.0°C with July (23.0°C),the warmest month, and January (6.0°C), the coldest. Mean annual precipitation, 118 cm, is fairly well distributed during the year except for rare periods of summer drought. Mean growing season is 181 days with the first freeze 20 October and the last freeze 22 April (Ross et al. 1981).

METHODS

The vascular flora was extensively collected from Feltner Lake and its contiguous habitats throughout the growing seasons of 1999 to 2002. A single reconnaissance collecting trip was made in 1987 and one trip in 1997. Manuals used for identification were Beal and Thieret (1986), Gleason and Cronquist (1991), and Strausbaugh and Core (1978). Plant nomenclature and classification followed Gleason and Cronquist (1991). All voucher specimens were deposited in the Berea College Herbarium (BEREA).

The annotated list includes each species scientific name, vernacular name, relative abun-

Table 1. Classification of vascular plants at Feltner Lake and environs, Laurel County, Kentucky.

Division	Families	Genera	Species	Native	Exotic	Species composition percent
Lycopodiophyta	2	2	4	4	0	1.14
Polypodiophyta	6	10	13	13	0	3.70
Pinophyta	2	3	3	2	0	0.86
Magnoliophyta	78	206	331	289	42	94.30
Magnoliopsida	64	147	234	204	30	66.67
Liliopsida	14	59	97	85	12	27.63
Totals	88	221	351	309	42	100.00

dance value, habitat(s), wetland status, and voucher specimen number.

Habitat designations of Feltner Lake are from personal reconnaissance and adapted from the wetland habitats of Carter and Burbank (1978) and Cowardin et al. (1979). Habitats were based on factors of topography, soils, hydrology, and floristic composition of existing vegetation in the study area. Wetland habitats were delineated by the presence of hydrophytic vegetation (>50% obligate, facultative wetland, and facultative species), from wetland hydrology indicators (e.g., water marks on trees, water saturated soils, drift lines, sediment deposits, dark water-stained leaves, and topographic drainage patterns), and the presence of hydric soils (USACE 1987). Relative abundance was adapted from Thompson and Jones (2001). Abundance categories are rare, 1–5 individuals or colonies; infrequent, 6–30 individuals or colonies; occasional, 31–100 individuals or colonies; frequent, 101–1000 individuals or colonies; and abundant, 1000s of individuals or colonies. One relative abundance value is given for each species, and it is inclusive for all habitats in which the taxon was found.

National Wetland Indicator Categories followed that of Reed (1988). Plants were designated as obligate wetland (OBL), >99% probability in wetlands; facultative wetland (FACW), 67–99% probability in wetlands, sometimes in non-wetlands; facultative (FAC), 34–66% probability in wetlands or non-wetlands; facultative upland (FACU), 1–33% probability in wetlands, sometimes in non-wetlands; and upland (UPL), <1% probability of being in wetlands. Positive (+) and negative (−) signs were included in the facultative categories to express the tendency to be at the wetter (+) or drier (−) end of that category. Not Categorized (NC) has been created for those species not listed or classified in the USFWS (1997). Wetland status for each taxon in this study has been determined from that National List, Northeastern Region 1.

Seventeen soil samples from the A horizon in seven terrestrial habitats were sampled for pH and chroma or soil color. Soils were collected with a stainless steel soil probe from the top 15 cm of the soil, placed in PCB tubes, and sent to Murray State University (MSU) for pH and chroma data. At MSU, soil pH was determined on a 1:1 volume ratio of air-dried soil and distilled water as described in Soil Quality Institute (1999). The soil-water mixture was shaken vigorously for 2 min and allowed to settle overnight. The pH of the water was measured using a two-point calibrated pH meter (Model 8005 VWR Scientific, West Chester, PA).

Soil color was determined as described in the Corps of Engineers Wetlands Delineation Manual (USACE 1987), using Munsell Soil Color Charts (Munsell Soil Color Charts 1998). Soils were determined to be hydric (soil range) if the chroma of the soil matrix was between 2 and under 3 and the soil included bright-colored mottles, or if the matrix was less than 2 without bright-colored mottles. Chroma 3 or greater are upland soils (USACE 1987).

RESULTS

Flora

The vascular plants of Feltner Lake and contiguous habitats were comprised of 88 families, 221 genera, and 351 specific and infraspecific taxa (Table 1). Taxa consisted of Lycopodiophyta (4), Polypodiophyta (13), Pinophyta (3), and Magnoliophyta (331). The largest families in species richness were Asteraceae (44), Poaceae (37), Cyperaceae (29), Fabaceae (16), Rosaceae (14), and Fagaceae and Rubiaceae (10 each). A total of 42 (11.97 %) were naturalized species. The largest genera were *Carex* (20), *Panicum* (11), *Quercus* (8), and *Polygonum* and *Eupatorium* (5 each). *Aconitum uncinatum,* a threatened plant species listed for Kentucky (KSNPC 2000), was found in the mesic oak forest at Feltner Lake. The 351 species at Feltner Lake and its habitats were composed of 48 OBL, 65 FACW, 53 FAC, 99 FACU, 29 UPL, and 57 NC species.

The species richness of the study area of Feltner Lake was analyzed using the species-area curve of Wade and Thompson (1991). From the equation, $S = 272A^{0.113}$, a predicted species richness (S), can be calculated by inserting a known area in hectares (A). For the study site of 16 ha, the predicted species richness is 371 species. Feltner Lake and environs is floristically rich for this small area of the Northern Cumberland Plateau within the Mixed Mesophytic Forest Region.

Habitats

Eight upland habitats were classified from the wettest to driest environments. These habitats formed narrow transitional ecotone bands or zones between other adjacent habitats (Figure 2). The six wetland habitats delineated were vegetated open water, emergent marsh, seasonally dewatered mudflats, sedge-grass meadow, gravelly creekbank, and oak swamp woods. The drier habitats were mesic oak forest and culturally derived habitat.

DISCUSSION

Wetland Habitats

Vegetated open water (VOW)—the permanent 2.7 ha of surface area of Feltner Lake (Figure 2). The VOW has a maximum depth of 4 m and does not have vegetation growing across the deepest areas. *Brasenia schreberi* forms extensive colonies in the more shallow zones of the lake. Other OBL aquatic species are *Lemna minor, Najas minor, Potamogeton diversifolius, P. nodosus,* and *Utricularia gibba.* The flora is restricted to these six OBL floating-leaved submergents, true submergents, and free-floating species.

Emergent marsh (EM)—the areas characterized by permanent or seasonal flooding in a banked zone completely surrounding Feltner Lake. The EM lies between the seasonally dewatered flats, sedge-grass meadow, oak swamp woods, and the mowed camp yard. Hydric soils have a mean pH of 4.8 and a chroma value of 2. Representative flora is made up of 27 OBL and 8 FACW amphibious plants. These plants typically have stems projecting out of the water and are rooted in mud. Characteristic species include *Alisma subcordatum, Carex lupulina, C. stipata, Eleocharis obtusa, E. tenuis, Juncus effusus* var. *solutus, Ludwigia palustris, Penthorum sedoides, Polygonum hydropiperoides, Proserpinaca palustris, Sagittaria australis, S. calycina, Scirpus cyperinus,* and *S. purshianus.* At the far north end of Feltner Lake near the headwater creek inlet is a stand of *Sparganium americanum* and *Typha latifolia.*

Seasonally dewatered mudflat (SDF)—the area surrounding Feltner Lake that is inundated for most of the year but becomes exposed because of water evaporation and water drawdown from lake leakage in summer and fall. Hydric soils have developed with a mean pH of 4.7 and a chroma of 2 and under 3. Characteristic species include *Ambrosia artemisiifolia, Bidens cernua, Cyperus flavescens, C. strigosus, Digitaria ischaemum, Diodia virginiana, Echinochloa muricata, Eclipta prostrata, Eragrostis pectinacea, Fimbristylis autumnalis, Lindernia dubia, Ludwigia palustris, Panicum dichotomiflorum, Polygonum* spp., *Rotala ramosior, Scirpus purshianus,* and *Xanthium strumarium.* The flora is represented in all wetland categories: 14 OBL, 11 FACW, 4 FAC, 7 FACU, and 2 UPL.

Sedge-grass meadow (SGM)—nearly flat areas with water-saturated hydric soils most of the year and with a dense graminoid plant cover. The SGM is covered with shallow water during times of increased rainfall in spring and fall. This narrow zone lies between the SDF, EM, and oak swamp woods on the western side of Feltner Lake and includes a small area by the side inlet on the northeast area (Figure 2). The hydric soils have a mean pH of 5.9 and a chroma between 2 and 3.

The flora consist of several graminoids from Cyperaceae, Poaceae, and Juncaceae. Characteristic plants include *Bidens frondosa, Carex frankii, C. lurida, Chelone glabra, Cyperus brevifolioides, Epilobium coloratum, Galium* *tinctorium, Hypericum mutilum, Juncus acuminatus, J. effusus* var. *solutus, Leersia oryzoides, Lobelia cardinalis, Panicum rigidulum, Polygonum sagittatum, Rhexia virginica, Scirpus atrovirens, Scutellaria lateriflora,* and *Spiraea tomentosa.* The vascular plants are comprised of 17 OBL, 31 FACW, and 6 FAC species.

Gravelly creekbank (GC)—least extensive wetland area, being found along a small creek on shale bedrock and sandstone gravel about 7 m below the earthen dam and including the dam spillway overflow (Figure 2). The GC is maintained by a dam leak and lake overflow throughout the seasons. It runs through the mesic oak forest and eventually leads to Lick Creek, which joins the Laurel River. The soils are hydric with a mean pH of 4.8 and chroma between 2 and 3. The combined area for the EM, SDF, SGM, and GC is 0.8 ha.

Characteristic herbs of the GC are *Boehmeria cylindrica, Cicuta maculata, Cinna arundinacea, Glyceria striata, Impatiens capensis, Leersia oryzoides, L. virginica, Lycopus virginicus, Mimulus alatus,* and *Pilea pumila.* Woody plants bordering the GC are *Betula nigra, Carpinus caroliniana, Liquidambar styraciflua, Lonicera japonica,* and *Sambucus canadensis.* Flora includes 6 OBL, 10 FACW, 7 FAC, and 4 FACU species.

Oak swamp woods (OSW)—the seasonally inundated or flooded area of 4.2 ha on the western, northwestern, and northern sides of Feltner Lake (Figure 2). The OSW has saturated gray hydric soils with a mean pH of 5.2 and a chroma value of 2. The OSW has no standing water and has several hydrological indicators present. This extensive zone lies between the SGM, EM, and mesic oak forest.

Quercus bicolor and *Q. palustris* are major indicator wetland oaks of the second largest major habitat of Camp Feltner. Other important upland canopy trees are *Acer rubrum, Betula nigra, Liquidambar styraciflua, Liriodendron tulipifera, Nyssa sylvatica, Q. alba,* and *Q. imbricaria.* A scrub-shrub border of the OSW with little herbaceous cover includes *Acer rubrum, Alnus serrulata, Betula nigra, Carpinus caroliniana, Cephalanthus occidentalis, Ilex verticillata,* and *Salix nigra.* Subcanopy trees and shrubs of the OSW include *Asimina triloba, Euonymus americana, Lindera benzoin, Vaccinium corymbosum,* and *Viburnum dentatum. Toxicodendron radicans* is the pre-eminent woody vine and *Smilax rotundifolia* is important.

Thelypteris noveboracensis is as an indicator species for the transitional ecotone of the OSW and the Mesic Oak Forest. Other important ferns are *Athyrium filix-femina* var. *asplenioides, Onoclea sensibilis, Osmunda cinnamomea, O. regalis* var. *spectabilis,* and *Woodwardia areolata.* Characteristic herbs are *Boehmeria cylindrica, Carex intumescens, C. radiata, C. debilis, Chasmanthium laxum, Cinna arundinacea, Habenaria clavellata, Leersia virginica, Microstegium vimineum, Panicum lanuginosum, Poa sylvestris, Rubus allegheniensis, R. hispidus, Senecio aureus, Thalictrum pubescens,* and *Viola cucullata.* Flora is composed of 8 OBL, 30 FACW, 24 FAC with only 6 FACU and 1 NC shrubs, trees, and herbs. Fifty-three of the swamp forest and wet meadow species listed by Braun (1937) were present at Feltner Lake, primarily in the the OSW and SGM habitats.

Upland Habitats

Mesic oak forest (MOF)—the area making up the majority of the forest vegetation of Camp Feltner and environs. A selected 6.1 ha band of MOF was surveyed around Feltner Lake where it joins the OSW, GC, and culturally derived habitats on the west, north, and south sides (Figure 2). The soils are forest soils with a mean pH of 4.9 and a chroma range from 3 to 6.

This large stand was dominated by mature *Pinus virginiana* with several oaks sharing dominance. Most of the mature *Pinus virginiana* has recently succumbed to the effects of the southern pine beetle (*Dendroctonus frontalis*). *Quercus alba* is the most important of all the oaks throughout the MOF. On the south and west sides of Feltner Lake, the dead stand of *Pinus virginiana* is interspersed among *Acer rubrum, Carya ovata, C. tomentosa, Liriodendron tulipifera, Nyssa sylvatica, Oxydendrum arboreum, Quercus falcata, Q. velutina,* and other canopy trees. On the northeast and north sides of Feltner Lake is a stand of predominantly mature *Carya ovata and Quercus alba* among saplings and pole-sized *Fagus grandifolia* and *Tsuga canadensis.* Other canopy trees are *Acer rubrum, Carya tomentosa, Liquidambar styraciflua, Lirio-*

dendron tulipifera, Nyssa sylvatica, Prunus serotina, and Quercus *rubra.* Subcanopy trees and shrubs include *Asimina triloba, Carpinus caroliniana, Cornus florida, Corylus americana, Euonymus americana, Ilex opaca, Lindera benzoin,* and *Viburnum acerifolium. Parthenocissus quinquefolia, Smilax rotundifolia,* and *Toxicodendron radicans* are the dominant woody vines intermixed with *Lonicera japonica* and *Vitis aestivalis.*

The MOF has the highest herbaceous species richness of the eight habitats at Feltner Lake. Important fern and fern allies are *Athyrium filix-femina* var. *asplenioides, Botrychium virginianum, Lycopodium obscurum, Polystichum acrostichoides, Thelypteris hexagonoptera,* and *T. noveboracensis.* Characteristic herbs include *Agrimonia rostellata, Brachyelytrum erectum, Circaea lutetiana* var. *canadensis, Desmodium nudiflorum, Galium triflorum, Geum canadense, Goodyera pubescens, Microstegium vimineum, Mitchella repens, Podophyllum peltatum, Potentilla simplex, Sanicula canadensis, Smilacina racemosa, Tipularia discolor,* and *Viola conspersa.*

One threatened species in Kentucky, *Aconitum uncinatum,* was found among a mixed MOF stand near the utility powerline-cut thicket. The naturalized *Ligustrum sinense, Morus alba,* and *Rhamnus frangula* were restricted to the MOF.

An early to mid-successional open woodland thicket has developed under the utility powerline-cut adjacent to the dam embankment of the mesic oak forest. This thicket represents a transitional ecotone of the MOF with the culturally derived mowed dam embankment. *Acer rubrum, Carya* spp., *Liquidambar styraciflua, Liriodendron tulipifera, Nyssa sylvatica, Oxydendrum arboreum, Prunus serotina, Quercus* spp., *Rhus copallina, R. glabra,* and *Robinia pseudoacacia* are cut-back trees in the powerline corridor. Shrubs and vines include *Corylus americana, Euonymus americana, Lonicera japonica,* and *Toxicodendron radicans.* Perennial herbs include *Coreopsis major, Desmodium rotundifolium, Eupatorium rotundifolium, Euphorbia corollata, Lespedeza intermedia, L. repens, Pycnanthemum pycnanthemoides, Rudbeckia hirta, Senecio anonymus, Solidago nemoralis,* and *Thaspium barbinode.* The vascular plants of the MOF include 4 FACW, 27 FAC, 61 FACU, 8 UPL, and 39 NC taxa.

Culturally derived habitat (CD)—ruderal areas of the extensive mowed and string-trimmed camp yard, the asphalt roadside, a gravel road west of the lake, and the yard borders with MOF (Figure 2). This area delineated for this study is ca. 2.2 ha. The forest soils have a mean pH of 6.4 and a chroma value of 3 to 4. This higher pH could be partly because of occasional liming of the mowed camp yard over the years.

Important perennial species of the mowed camp yard and other ruderal areas include *Carex* caroliniana, C. *glaucodea, Danthonia spicata, Festuca elatior, Hypericum stragulum, Juncus tenuis, Luzula echinata, Panicum laxiflorum, Plantago lanceolata, P. rugelii, Potentilla canadensis,* and *Salvia lyrata.* Representative exotic annuals are *Digitaria ischaemum, D. sanguinalis, Lespedeza striata,* and *Trifolium repens.* The flora of the CD is represented by 9 FAC, 36 FACU, 19 UPL, and 21 NC species. Forty of 42 naturalized taxa were found in this habitat.

CONCLUSIONS

Feltner Lake and contiguous habitats have 351 species catalogued for the 16-ha area with only a −5.6 per cent deviation value. The oak swamp woods is one of the rarest habitats in eastern Kentucky. The flora of the eight habitats follow a topographic-moisture-soil gradient from the wettest VOW to the driest CD habitats. The six wetland habitats are dominated by OBL, FACW, and FAC species. The two drier habitats are represented mostly by FACU, UPL, and NC taxa. The National Wetland Indicator Categories were useful indicators of the flora in the habitats of Feltner Lake. All NC species should be properly reclassified in future National Wetland Indicator Category lists. The majority would best fit in the FACU and UPL categories.

Of the 17 soil samples analyzed for soil chroma and pH values, hydric soils were identified in the emergent marsh, seasonally dewatered flats, sedge-grass meadow, gravelly creekbank, and oak swamp forest. The mean pH of these hydric soils was 5.3 with a range from 4.6 to 5.8; the chroma value was between 2 and under 3. Forest soils were present in the mesic oak forest and mowed camp yard.

These soils had a mean pH of 4.8 with a range of 4.6–4.9 and a chroma variation of from 3 to 6. Mean pH of all 17 samples was 5.3 with a range from 4.6 to 6.9; the chroma varied from 2 to 6.

ANNOTATED LIST OF VASCULAR PLANTS

Species are listed alphabetically by family, genus, and species. An asterisk (*) before a scientific name indicates an exotic taxon. Relative abundance values are rare, infrequent, occasional, frequent, and abundant. The code for the eight habitats are VOW (vegetated open water), SDF (seasonally dewatered mudflats), EM (emergent marsh), SGM (sedge-grass meadow), GC (gravelly creekbank), OSW (oak swamp woods), MOF (mesic oak forest), and CD (culturally derived habitat). National Wetland Indicator Categories are OBL (obligate), FACW (facultative wetland), FAC (facultative), FACU (facultative upland), UPL (upland), and NC (not categorized or not included). The three facultative categories are subdivided by (+) and (−) signs toward upper and lower moisture limits. Representative vouchers list the year collected, a hyphen, and then a specimen number in italics.

LYCOPODIOPHYTA

Lycopodiaceae

Lycopodium digitatum Dillen ex A. Braun (southern ground-cedar). Rare; MOF. [FACU−]. *00-408*

L. lucidulum Michx. (shining clubmoss). Rare; MOF. [FACW−]. *02-293*

L. obscurum L. (ground-pine). Occasional; MOF. [FACU]. *01-700*

Selaginellaceae

Selaginella apoda (L.) Spring (meadow spikemoss). Rare; SGM. [FACW]. *00-15*

POLYPODIOPHYTA

Aspleniaceae

Asplenium platyneuron (L.) Oakes (ebony spleenwort). Rare; MOF. [FACU]. *02-62*

Athyrium filix-femina (L.) Roth var. *asplenioides* (Michx.) Farw. (southern lady fern). Abundant; OSW, MOF. [FAC]. *87-504*

Polystichum acrostichoides (Michx.) Schott (Christmas fern). Abundant; OSW, MOF. [FACU−]. *99-1044*

Thelypteris hexagonoptera (Michx.) Weatherby (broad beech fern). Rare; MOF. [FAC]. *02-257*

T. noveboracensis (L.) Nieuwl. (New York fern). Abundant; OSW, MOF. [FAC]. *00-399*

Blechnaceae

Woodwardia areolata (L.) Moore (netted chain fern). Infrequent; OSW. [FACW+]. *99-1030*

Onocleaceae

Onoclea sensibilis L. (sensitive fern). Occasional; OSW. [FACW]. *87-532*

Ophioglossaceae

Botrychium dissectum Spreng. var. *obliquum* (Muhl.) Clute (lace-frond grape fern). Rare; OSW. [FAC]. *00-580*

B. virginianum (L.) Sw. (rattlesnake-fern). Frequent; MOF. [FACU]. *02-121*

Ophioglossum vulgatum L. (adder's tongue). Rare; CD. [NC]. *00-95*

Osmundaceae

Osmunda regalis L. var. *spectabilis* (Willd.) A. Gray (royal fern). Occasional; OSW. [OBL]. *87-525*

O. cinnamomea L. (cinnamon fern). Occasional; OSW. [FACW]. *00-138*

Schizaeaceae

Lygodium palmatum (Bernh.) Swartz (climbing fern). Rare; MOF, OSW. [FACW]. *99-1140*

PINOPHYTA

Cupressaceae

Juniperus virginiana L. (eastern red-cedar). Rare; MOF. [FACU]. *02-456*

Pinaceae

Pinus virginiana P. Mill. (Virginia pine). Frequent; MOF. [NC]. *00-565*

Tsuga canadensis (L.) Carr. (eastern hemlock). Occasional; MOF. [FACU]. *01-613*

MAGNOLIOPHYTA

Aceraceae

Acer rubrum L. (red maple). Abundant; OSW, MOF. [FAC]. *00-751*

A. saccharinum L. (silver maple). Occasional; OSW. [FACW]. *99-1124*

Alismataceae

Alisma subcordatum Raf. (southern water-plantain). Frequent; EM, SDF. [OBL]. *87-536*

Sagittaria australis (J.G. Smith) Small (Appalachian arrowhead). Occasional; EM, SDF. [OBL]. *99-1005*

S. calycina Engelm. (Mississippi arrowhead). Occasional; EM, SDF. [OBL]. *99-1006*

Anacardiaceae

Rhus copallina L. (winged sumac). Infrequent; MOF. [FACU−]. *02-275*

R. glabra L. (smooth sumac). Infrequent; MOF. [FACU]. *02-313*

Toxicodendron radicans (L.) Kuntze (poison ivy). Abundant; GC, OSW, MOF. [FAC]. *00-750*

Annonaceae

Asimina triloba (L.) Dunal (pawpaw). Occasional; OSW, MOF. [FACU−]. *99-1127*

Apiaceae

Cicuta maculata L. (water-hemlock). Occasional; GC, SGM. [OBL]. *99-1133*

Cryptotaenia canadensis (L.) DC. (honewort). Infrequent; OSW. [FAC]. *02-263*

**Daucus carota* L. (wild carrot). Occasional; CD. [UPL]. *02-276*

Oxypolis rigidior (L.) Raf. (common water-dropwort). Rare; OSW. [OBL]. *01-710*

Sanicula canadensis L. (black snakeroot). Frequent; MOF. [UPL]. *00-237*

S. smallii E. Bickn. (southern snakeroot). Occasional; MOF. [NC]. *02-315*

Thaspium barbinode (Michx.) Nutt. (hairy-jointed meadow-parsnip). Rare; MOF. [UPL]. *02-63*

Aquifoliaceae

Ilex opaca Aiton (American holly). Infrequent; MOF. [FACU]. *99-1112*

I. verticillata (L.) A. Gray (winterberry). Occasional; OSW. [FACW+]. *87-528*

Araliaceae

Aralia racemosa L. (American spikenard). Infrequent; MOF. [NC]. *02-294*

Aristolochiaceae

Aristolochia serpentaria L. (Virginia snakeroot). Rare; MOF. [UPL]. *02-308*

Asteraceae

**Achillea millefolium* L. (common yarrow). Infrequent; CD. [FACU]. *00-225*

Ambrosia artemisiifolia L. (common ragweed). Frequent; CD, SDF. [FACU]. *99-1058*

Antennaria plantaginifolia (L.) Richardson (plantain-pussytoes). Occasional; MOF. [NC]. *02-251*

Aster divaricatus L. (white heart-leaved aster). Occasional; MOF. [NC]. *01-702*

A. dumosus L. (bushy aster). Occasional; SGM. [FAC]. *99-1025*

A. lateriflorus (L.) Britt. (calico aster). Occasional; OSW. [FACW−]. *00-759*

A. pilosus Willd. (white heath aster). Occasional; CD. [UPL]. *99-1135*

Bidens comosa (A. Gray) Wieg. (strawberry beggars-ticks). Abundant; EM, SDF. [FACW]. *99-1070*

B. frondosa L. (Devil's beggar-ticks). Abundant; EM, SDF. [FACW]. *99-1074*

B. polylepis S.F. Blake (Ozark tickseed-sunflower). Rare; SGM. [FACW]. *02-409*

B. vulgata Greene (tall beggars-ticks). Occasional; SDF. [FACW+]. *99-1075*

Cacalia atriplicifolia L. (pale Indian plantain). Rare; MOF. [NC]. *02-408*

**Chrysanthemum leucanthemum* L. (ox-eye daisy). Infrequent; CD. [UPL]. *02-259*

**Cirsium vulgare* (Savi) Tenore (bull thistle). Rare; CD. [FACU−]. *02-326*

Conyza canadensis(L.) Cronq. (horseweed). Infrequent; CD. [UPL]. *02-405*

Coreopsis auriculata L. (lobed tickseed). Infrequent; MOF. [NC]. *02-65*

C. major Walt. (forest tickseed). Infrequent; CD. [NC]. *02-448*

**Eclipta prostrata* (L.) L. (yerba-de-tajo). Infrequent; SDF. [FAC]. *00-570*

Elephantopus carolinianus Willd. (elephant's-foot). Rare; MOF. [FACU]. *01-608*

Erechtites hieraciifolia (L.) Raf. ex DC. (fireweed). Occasional; CD, SDF. [FACU]. *99-1035*

Erigeron annuus (L.) Pers. (annual fleabane). Infrequent; CD. [FACU]. *02-269*

Erigeron philadelphicus L. (Philadelphia fleabane). Occasional; CD. [FACU]. *00-69*

Eupatorium coelestinum L. (blue mistflower). Infrequent; SGM. [FAC]. *99-1040*

E. fistulosum Barratt (hollow-stemmed joe-pye weed). Occasional; SGM. [FACW]. *99-1020*

E. perfoliatum L. (perfoliate boneset). Infrequent; SGM. [FACW+]. *00-391*

E. rotundifolium L. (round-leaved boneset). Occasional; MOF. [FAC−]. *99-1096*

E. rugosum Houtt. (white snakeroot). Occasional; MOF. [FACU−]. *01-716*

Gnaphalium obtusifolium L. (old-field balsam). Rare; CD. [NC]. *02-441*

G. purpureum L. (purple cudweed). Infrequent; CD. [NC]. *02-53*

Helianthus microcephalus Torr. & A. Gray (small-headed sunflower). Rare; MOF. [NC]. *02-452*

Hieracium gronovii L. (hairy hawkweed). Infrequent; CD. [UPL]. *02-443*

Krigia biflora (Walt.) S.F. Blake (orange dwarf-dandelion). Infrequent; CD, MOF. [FACU]. *00-62*

Lactuca floridana (L.) Gaertn. (blue lettuce). Rare; MOF. [FACU−]. *00-569*

Prenanthes trifoliata (Cass.) Fern. (lion's-foot). Rare; MOF. [FACU−]. *02-450*

Rudbeckia hirta L. (brown-eyed Susan). Infrequent; CD, MOF. [FACU−]. 02-334

Senecio anonymus A. Wood (Appalachian groundsel). Infrequent; CD, MOF. [UPL]. *02-61*

S. aureus L. (heart-leaved groundsel). Occasional; OSW. [FACW]. *00-64*

Silphium trifoliatum L. (whorled rosinweed). Rare; CD. [NC]. *02-332*

Solidago canadensis L. var. *scabra* Torr. & A. Gray (common goldenrod). Infrequent; CD. [FACU]. *02-401*

Solidago gigantea Aiton (tall Goldenrod). Infrequent; SGM. [FACW]. *02-335*

S. nemoralis Aiton (old-field goldenrod). Infrequent; MOF. [NC]. *02-418*

S. rugosa P. Mill. (wrinkled-leaved goldenrod) Infrequent; SGM. [FAC]. *02-410*

Vernonia gigantea (Walt.) Trel. (tall ironweed). Rare; SGM. [FAC]. *02-411*

Xanthium strumarium L. (common cocklebur). Abundant; SDF. [FAC]. *99-1064*

Balsaminaceae

Impatiens capensis Meerb. (spotted touch-me-not). Abundant; GC, SGM. [FACW]. *99-1042*

Berberidaceae

Podophyllum peltatum L. (May-apple). Occasional; MOF. [FACU]. *00-17*

Betulaceae

Alnus serrulata (Aiton) Willd. (smooth alder). Frequent; OSW. [OBL]. *99-1100*

Betula nigra L. (river birch). Frequent; OSW. [FACW]. *99-1086*

Carpinus caroliniana Walt. (Carolina hornbeam). Frequent; OSW, MOF. [FAC]. *00-240*

Corylus americana L. (American hazelnut). Occasional; MOF. [FACU−]. *00-754*

Ostrya virginiana (P. Mill.) K. Koch (eastern hophornbeam). Infrequent; MOF. [FACU−]. *99-1118*

Bignoniaceae

Bignonia capreolata L. (crossvine). Infrequent; OSW. [FAC+]. *00-129*

Brassicaceae

**Brassica rapa* L. (field mustard). Rare; CD. [NC]. *00-33*

**Cardamine hirsuta* L. (hairy bittercress). Occasional; CD. [FACU]. *00-31*

**Draba verna* L. (Whitlow-grass). Occasional; CD. [NC]. *00-27*

Lepidium virginicum L. (Virginia pepper-grass). Infrequent; CD. [FACU−]. *02-440*

Cabombaceae

Brasenia schreberi J.F. Gmelin (water-shield). Abundant; VOW. [OBL]. *87-524*

Campanulaceae

Lobelia cardinalis L. (Cardinal flower). Infrequent; SGM. [FACW+]. *97-803*

L. inflata L. (Indian-tobacco). Occasional; CD, SDF, MOF. [FACU]. *99-1073*

L. puberula Michx. (downy lobelia). Infrequent; SGM. [FACW−]. *01-711*

Caprifoliaceae

**Lonicera japonica* Thunb. (Japanese honeysuckle). Frequent; GC, OSW, MOF. [FAC]. *99-1094*

Sambucus canadensis L. (common elderberry). Infrequent; GC, OSW. [FACW]. *01-615*

Viburnum acerifolium L. (maple-leaved viburnum). Occasional; MOF. [UPL]. *02-297*

V. dentatum L. (arrow-wood). Infrequent; OSW. [FAC]. *00-228*

Caryophyllaceae

**Cerastium brachypetalum* Pers. (long-pediceled chickweed). Infrequent; CD. [NC]. *00-68*

**C. viscosum* L. (clammy chickweed). Occasional; CD. [UPL]. *02-45*

**C. vulgatum* L. (mouse-eared chickweed). Occasional; CD. [NC]. *00-66*

Silene virginica L. (fire pink). Rare; MOF. [NC]. *00-93*

**Stellaria media* (L.) Villars (common chickweed). Frequent; CD. [UPL]. *02-75*

S. pubera Michx. (giant chickweed). Infrequent; MOF. [NC]. *00-18*

Celastraceae

Euonymus americana L. (strawberry-bush). Frequent; MOF. [NC]. *99-1097*

Clusiaceae

Hypericum mutilum L. (small-flowered St. John's-wort). Frequent; SDF, SGM. [FACW]. *99-1083*

H. punctatum Lam. (dotted St. John's-wort). Occasional; MOF. [FAC−]. *00-756*

H. stragulum P. Adams & Robson (St. Andrew's-cross). Occasional; CD. [FACU]. *02-422*

Triadenum tubulosum (Walt.) Gleason (marsh St. John's-wort). Occasional; EM. [OBL]. *99-1046*

Commelinaceae

**Commelina communis* L. (Asiatic dayflower). Infrequent; SGM. [FAC−]. *99-1103*

Cornaceae

Cornus florida L. (flowering dogwood). Occasional; MOF. [FACU−]. *01-609*

Nyssa sylvatica Marsh. (blackgum). Abundant; OSW, MOF. [FAC]. *99-1087*

Cuscutaceae

Cuscuta pentagona Engelm. (field dodder). Frequent; GC, SGM. [NC]. *99-1016*

Cyperaceae

Carex albicans Willd. var. *albicans* (white-tinged sedge). Infrequent; MOF. [NC]. *00-70*

C. albolutescens Schwein. (whitish-yellow sedge). Infrequent; OSW. [FACW]. 02-41

C. amphibola Steud. (narrow-leaf sedge). Infrequent; MOF. [FAC]. *00-130*

C. caroliniana Schwein. (Carolina sedge). Occasional; MOF. [FACU]. *00-133*

C. cephalophora Muhl. ex Willd. (oval-headed sedge). Infrequent; CD. [FACU]. *02-39*

C. crinita Lam. (fringed sedge). Occasional; EM, OSW. [OBL]. *87-517*

C. debilis Michx. var. *debilis* (white-edged sedge). Occasional; OSW. [FAC]. *00-132*

C. frankii Kunth (bristly cattail sedge). Infrequent; SGM. [OBL]. *87-501*

C. glaucodea Tuckerm. (blue sedge). Frequent; CD. [FAC]. *02-31*

C. gracilescens Steud. (looseflower sedge). Occasional; MOF. [FACU]. *00-88*

C. gracillima Schwein. (graceful sedge). Occasional; OSW. [FACU]. *87-508*

C. intumescens Rudge (bladder sedge). Frequent; OSW. [FACW+]. *87-509*

C. lupulina Muhl. ex Willd. (large hop-sedge). Occasional; OSW, SGM. [OBL]. *87-519*

C. lurida Wahlenb. (yellow-green sedge). Frequent; OSW, SGM. [OBL]. *87-503*

C. radiata (Wahlenb.) Small (radiate sedge). Occasional; OSW. [NC]. *02-36*

C. rosea Schkuhr (rose sedge). Occasional; MOF. [NC]. *00-226*

C. squarrosa L. (common cattail sedge). Infrequent; SGM. [FACW]. *87-512*

C. stipata Muhl. var. *stipata* (crowded sedge). Infrequent; EM, GC. [OBL]. *00-127*

C. swanii (Fern.) Mack. (Swan's sedge). Occasional; CD. [FACU]. *02-40*

C. tribuloides Wahlenb. (blunt broom-sedge). Infrequent; SGM. [FACW+]. *87-516*

Cyperus bipartitus Torr. (red brook flatsedge). Frequent; EM, SDF. [FACW+]. *97-809*

C. brevifolioides Thieret & Delahoussaye (small-leaved flatsedge). Abundant; EM, SGM. [FACW]. *00-588*

C. flavescens L. (yellow flatsedge). Frequent; EM, SDF. [OBL]. *97-807*

C. strigosus L. (lean flatsedge). Infrequent; EM, SDF. [FACW]. *87-515*

Eleocharis ovata (Roth) Roem. & Schult. (blunt-lobed spikerush). Abundant; EM, SDF. [OBL]. *97-808*

E. tenuis (Willd.) Schult. (slender spikerush). Abundant; EM, SGM. [OBL]. *02-52*

Fimbristylis autumnalis (L.) Roem. & Schult.

(slender fimbry). Abundant; SDF; SGM. [FACW+]. *87-523*

Rhynchospora capitellata (Michx.) Vahl (common beakrush). Infrequent; SGM. [OBL]. *87-502*

Scirpus atrovirens Willd. (black-green bulrush). Infrequent; SGM. [OBL]. *00-223*

S. cyperinus (L.) Kunth (woolgrass). Frequent; EM, SGM. [FACW+]. *99–1013*

S. purshianus Fern. (weak-stalked bulrush). Abundant; EM, SDF. [OBL]. *97-806*

S. validus Vahl (soft-stemmed bulrush). Rare; EM. [OBL]. *99-1004*

Dioscoreaceae

Dioscorea villosa L. (wild yam). Occasional; MOF. [FAC+]. *00-571*

Ericaceae

Oxydendrum arboreum (L.) DC. (sourwood). Occasional; MOF. [UPL]. *00-401*

Rhododendron periclymenoides (Michx.) Shinners (pinxter-flower). Rare; OSW. [FAC]. *00-97*

Vaccinium corymbosum L. (highbush blueberry). Occasional; OSW. [FACW−]. *00-755*

Euphorbiaceae

Acalypha rhomboidea Raf. (rhombic copperleaf). Occasional; CD. [NC]. *99-1081*

Euphorbia corollata L. (flowering spurge). Infrequent; MOF. [NC]. *00-418*

E. maculata L. (spotted milk spurge). Frequent; CD, SDF. [FACU−]. *99-1080*

E. nutans Lagasca (eyebane spurge). Occasional; CD, SDF. [FACU−]. *99-1072*

Fabaceae

Amphicarpaea bracteata (L.) Fern. (hog-peanut). Frequent; GC. [FAC]. *01-606*

Apios americana Medik. (ground-nut). Infrequent; OSW. [FACW]. *87-537*

Chamaecrista nictitans (L.) Moench (wild sensitive pea). Infrequent; CD. [FACU−]. *02-320*

Desmodium glabellum (Michx.) DC. (smooth tick-trefoil). Infrequent; MOF. [NC]. *02-324*

D. rotundifolium DC. (round-leaved tick-trefoil). Infrequent; MOF. [NC]. *02-265*

D. nudiflorum (L.) DC. (naked tick-trefoil). Occasional; MOF. [NC]. *00-407*

D. paniculatum (L.) DC. (panicled tick-trefoil). Infrequent; MOF. [UPL]. *02-323*

Lathyrus latifolius L. (everlasting-pea). Rare; CD. [NC]. *02-345*

Lespedeza intermedia (S. Wats.) Britt. (wand lespedeza). Occasional; CD, MOF. [NC]. *00-556*

L. repens (L.) Barton (smooth trailing lespedeza). Occasional; CD, MOF. [NC]. *02-416*

**L. striata* (Thunb.) Hook. & Arnott (Japanese lespedeza). Abundant; CD. [FACU]. *02-328*

**Medicago lupulina* L. (black medic). Occasional; CD. [UPL]. *00-236*

Robinia pseudoacacia L. (black locust). Infrequent; MOF. [FACU−]. *02-346*

**Trifolium campestre* Schreber (pinnate hop clover). Infrequent; CD. [NC]. *02-66*

**T. pratense* L. (red clover). Occasional; CD. [FACU−]. *02-60*

**T. repens* L. (white clover). Frequent; CD. [FACU−]. *02-78*

Fagaceae

Castanea dentata (Marsh.) Borkh. (American chestnut). Rare; MOF. [NC]. *02-260*

Fagus grandifolia Ehrh. (American beech). Frequent; MOF. [FACU]. *99-1114*

Quercus alba L. (white oak). Abundant; OSW, MOF. [FACU]. *00-420*

Q. bicolor Willd. (swamp white oak). Occasional; OSW. [FACW+]. *00-753*

Q. falcata Michx. (southern red oak). Infrequent; MOF. [FACU-]. *00-409*

Q. imbricaria Michx. (shingle oak). Infrequent; MOF. [FAC]. *99-1122*

Q. palustris Muenchh. (pin oak). Occasional; OSW. [FACW]. *01-506*

Q. rubra L. (northern red oak). Infrequent; MOF. [FACU-]. *00-572*

Q. stellata Wangenh. (post oak). Infrequent; MOF. [UPL]. *00-568*

Q. velutina Lam. (black oak). Occasional; MOF. [UPL]. *99-1090*

Geraniaceae

Geranium maculatum L. (wild geranium). Occasional; MOF. [FACU]. *00-72*

Haloragaceae

Proserpinaca palustris L. (common mermaidweed). Abundant; EM, SDF. [OBL]. *97-805*

Hamamelidaceae

Liquidambar styraciflua L. (sweetgum). Frequent; OSW, MOF. [FAC]. *99-1010*

Iridaceae

Iris virginica L. (southern blue iris). Rare; EM, OSW. [OBL]. *87-518*

Sisyrinchium angustifolium P. Mill. (blue-eyed grass). Rare; SGM. [FACW−]. *00-144*

Juglandaceae

Carya glabra (P. Mill.) Sweet (pignut hickory). Occasional; MOF. [FACU−]. *00-575*

C. ovata (P. Mill.) Koch (shagbark hickory). Frequent; MOF. [FACU]. *00-427*

C. tomentosa (Poir.) Nutt. (mockernut hickory). Frequent; MOF. [FACU]. *02-256*

Juncaceae

Luzula echinata (Small) F.J. Herm. (woodrush). Occasional; CD, MOF. [FACU]. *00-65*

Juncus acuminatus Michx. (sharp-pointed rush). Frequent; EM, SGM. [OBL]. *87-534*

J. effusus L. var. *solutus* Fern. & Wieg. (soft rush). Frequent; EM, SGM. [OBL]. *87-520*

J. marginatus Rostk. (margined rush). Infrequent; SGM. [FACW]. *00-413*

J. tenuis Willd. var. *tenuis* (slender path rush). Frequent; CD. [FAC−]. *00-564*

Lamiaceae

Lycopus virginicus L. (Virginia bugle-weed). Occasional; EM, GC, SGM. [OBL]. *01-708*

Prunella vulgaris L. (self-heal). Occasional; CD, GC, MOF. [FACU+]. *01-605*

Pycnanthemum pycnanthemoides (Leavenw.) Fern. (hoary mt. mint). Occasional; CD, MOF. [NC]. *02-291*

Salvia lyrata L. (wild sage). Occasional; CD. [UPL]. *00-145*

Scutellaria incana Biehler (downy skullcap). Infrequent; MOF. [NC]. *00-757*

Scutellaria integrifolia L. (large-flowered skullcap). Infrequent; MOF. [FACW]. *00-241*

S. lateriflora L. (mad-dog skullcap). Occasional; SGM. [FACW+]. *99-1018*

Lauraceae

Lindera benzoin (L.) Blume (spicebush). Occasional; OSW, MOF. [FACW−]. *01-709*

Sassafras albidum (Nutt.) Nees (Sassafras). Occasional; MOF. [FACU]. *00-752*

Lemnaceae

Lemna minor L. (lesser duckweed). Abundant; VOW. [OBL]. *87-507*

Lentibulariaceae

Utricularia gibba L. (creeping bladderwort). Abundant; VOW. [OBL]. *87-529*

Liliaceae

Lilium canadense L. (wild yellow lily). Rare; OSW. [FAC+]. *87-538*

Medeola virginiana L. (Indian cucumber-root). Occasional; MOF. [NC]. *00–146*

Polygonatum biflorum (Walt.) Ell. (Solomon's seal). Infrequent; MOF. [FACU]. 02-108

Smilacina racemosa (L.) Desf. (false Solomon's seal). Frequent; MOF. [FACU−]. *00–137*

Uvularia perfoliata L. (mealy bellwort). Frequent; MOF. [FACU]. *00-77*

U. sessilifolia L. (sessile-leaved bellwort). Occasional; MOF. [FACU−]. *00-71*

Linaceae

Linum striatum Walt. (ridge-stemmed yellow flax). Rare; SGM. [FACW]. *02-266*

Lythraceae

Rotala ramosior (L.) Koehne (toothcup). Abundant; EM, SDF. [OBL]. *99-1137*

Magnoliaceae

Liriodendron tulipifera L. (yellow-poplar), Frequent; OSW, MOF. [FACU]. *99-1111*

Magnolia macrophylla Michx. (big-leaved magnolia). Infrequent; MOF. [NC]. *02-298*

Malvaceae

**Sida spinosa* L. (prickly mallow). Infrequent; SDF. [UPL]. *99-1119*

Melastomataceae

Rhexia virginica L. (wing-stemmed meadow-beauty). Occasional; SGM. [OBL]. *99-1043*

Moraceae

**Morus alba* L. (white mulberry). Rare; CD. [UPL]. *02-312*

M. rubra L. (red muberry). Infrequent; MOF. [FACU]. *02-338*

Najadaceae

Najas minor Allioni (lesser water naiad). Abundant; VOW. [OBL]. *00-406*

Oleaceae

**Ligustrum sinense* Lour. (Chinese privet). Rare; MOF. [FACU]. *01-614*

Onagraceae

Circaea lutetiana L. var. *canadensis* L. (enchanter's nightshade). Frequent; MOF. [FACU]. *00-227*

Epilobium coloratum Biehler (eastern willow-herb). Occasional; SGM. [FACW+]. *99-1037*

Ludwigia alternifolia L. (seedbox). Rare; SGM. [FACW+]. *00-400*

L. palustris (L.) Ell. (common water-purslane). Abundant; EM, SDF. [OBL]. *00-578*

Orchidaceae

Goodyera pubescens (Willd.) R. Br. ex Aiton (rattlesnake plantain). Rare; MOF. [FACU]. *02-295*

Habenaria clavellata (Michx.) Spreng. (club-spur orchid). Rare; GC, OSW. [FACW+]. *87-533*

Tipularia discolor (Pursh) Nutt. (cranefly orchid). Infrequent; MOF. [FACU]. *99-1110*

Oxalidaceae

Oxalis dillenii Jacq. (yellow wood-sorrel). Occasional; CD. [NC]. *02-64*

Passifloraceae

Passiflora lutea L. var. *glabriflora* Fern. (yellow passion-flower). Rare; MOF. [NC]. *02-296*

Phytolaccaceae

Phytolacca americana L. (pokeberry). Occasional; CD. [FACU+]. *99-1104*

Plantaginaceae

**Plantago lanceolata* L. (English plantain). Frequent; CD. [UPL]. *02–48*

P. rugelii Dcne. (Rugel's plantain). Abundant; CD. [FACU]. *02-271*

P. virginica L. (Virginia plantain). Infrequent; CD. [UPL]. *02-69*

Poaceae

Agrostis perennans (Walt.) Tuckerm. (autumn bent grass). Infrequent; GC. [FACU]. *02-325*

**Anthoxanthum odoratum* L. (sweet vernal grass). Rare; CD. [FACU]. *02-74*

Brachyelytrum erectum L. (brachyelytrum). Frequent; MOF. [NC]. *00-388*

Chasmanthium laxum (L.) Yates (lax wild oats). Frequent; OSW, MOF. [FAC]. *87-531*

Cinna arundinacea L. (common woodreed). Occasional; GC, OSW. [FACW]. *00-393*

**Dactylis glomerata* L. (orchard grass). Occasional; CD. [FACU]. *02-102*

**Digitaria ischaemum* (Schreber) Muhl. (smooth crab grass). Abundant; CD, SDF. [UPL]. *99-1077*

**D. sanguinalis* (L.) Scop. (northern crab grass). Frequent; CD. [FACU−]. *02-327*

Echinochloa muricata (P. Beauv.) Fern. (Barnyard-grass). Occasional; SDF. [FACW+]. *99-1039*

**Eleusine indica* (L.) Gaertn. (yard grass). Infrequent; CD. [FACU−]. *02-346*

Eragrostis pectinacea (Michx.) Nees ex Steud. (Carolina love grass). Abundant; SDF. [FAC]. *99-1059*

**Festuca elatior* L. (tall fescue]. Abundant; CD. [FACU−]. *02-56*

Glyceria striata (Lam.) Hitchc. (fowl manna grass). Frequent; GC, OSW. [OBL]. *00-149*

**Holcus lanatus* L. (common velvet grass). Rare; CD. [FACU]. *00-234*

Leersia oryzoides (L.) Swartz (rice cut grass). Abundant; EM, GC, SGM. [OBL]. *99-1108*

L. virginica Willd. (white grass). Frequent; GC, OSW. [FACW]. 00-398

**Microstegium vimineum* (Trin.) A. Camus (Nepalese eulalia). Abundant; GC, OSW, MOF. [FAC]. *99-1095*

Muhlenbergia sylvatica Torr. ex A. Gray (forest muhly). Infrequent; GC, OSW. [FAC+]. *00-586*

Panicum anceps Michx. (beaked panicum). Infrequent; MOF. [FAC]. *02-292*

P. boscii Poir. (large-fruited panicum). Occasional; MOF. [NC]. *00-422*

P. capillare L. (old witch grass). Occasional; CD, SDF. [FAC−]. *99-1067*

P. clandestinum L. (deer-tongue panicum). Occasional; GC, SGM. [FAC+]. *99-1017*

P. dichotomiflorum Michx. (spreading witch grass). Frequent; SDF. [FACW−]. *99-1050*

P. dichotomum L. (bushy panicum). Frequent; OSW, MOF. [FAC]. *00-224*

P. flexile (Gattinger) Scribn. (wiry witch grass). Occasional; SDF. [FACU]. *99-1082*

P. lanuginosum Ell. (hairy panicum). Frequent; CD, OSW, SGM. [FAC]. *99-1099*

P. laxiflorum Lam. (lax panicum). Abundant; CD. [FACU−]. *02-91*

P. polyanthes Schultes (many-flowered panicum). Occasional; GC, MOF. [FACU]. *02-273*

P. rigidulum Bosc ex Nees (Munro grass). Frequent; EM, SGM. [FACW+]. *87-535*

Paspalum pubiflorum Rupr. var. *glabrum* Vasey (glabrous bead grass). Occasional; CD. [FAC]. *99-1052*

**Poa annua* L. (spear grass). Occasional; CD. [FACU]. *00-25*

P. autumnalis Vahl. (autumn blue grass). Frequent; OSW. [FACW−]. *00-128*

P. cuspidata Nutt. (early blue grass). Occasional; MOF. [NC]. *00-19*

**P. pratensis L.* (Kentucky blue grass). Abundant; CD. [FACU]. *02-43*

**Setaria glauca* (L.) P. Beauv. (yellow foxtail). Infrequent; CD. [NC]. *02-447*

Sphenopholis obtusata (Michx.) Scribn. var. *major* (Torr.) K. S. Erdman (wedge grass). Infrequent; CD. [FAC−]. *02-58*

Tridens flava (L.) A.S. Hitchc. (purpletop). Occasional; CD. [FAC−]. *00-582*

Polemoniaceae

Phlox maculata L. (meadow phlox). Occasional; OSW. [FACW]. *87-521*

Polygalaceae

Polygala ambigua Nutt. (loose milkwort). Rare; CD. [UPL]. *02-343*

Polygonaceae

**Polygonum cespitosum* Blume var. *longisetum* (DeBruyn) Stewart (Asiatic water-pepper). Frequent; CD, SDF. [FACU−]. *87-513*

P. hydropiperoides Michx. (false water-pepper). Abundant; EM, SGM. [OBL]. *99-1078*

**P. persicaria* L. (lady's-thumb). Frequent; SDF. [FACW]. *87-514*

P. sagittatum L. (arrow-leaved tear-thumb). Occasional; SGM. [OBL]. *99-1076*

P. virginianum L. (jumpseed). Infrequent; OSW, MOF. [FAC]. *01-601*

**Rumex acetosella* L. (sheep sorrel). Occasional; CD. [UPL]. *02-49*

Portulacaceae

Claytonia virginica L. (spring beauty). Infrequent; MOF. [FAC]. *00-16*

Potamogetonaceae

Potamogeton diversifolius Raf. (snailseed pondweed). Abundant; VOW. [OBL]. *00-232*

P. nodosus Poir. (longleaf pondweed). Infrequent; VOW. [OBL]. *87-506*

Primulaceae

Lysimachia lanceolata Walt. (lance-leaved loosestrife). Occasional; SGM. [FAC]. *87-500*

Samolus floribundus HBK. (water-pimpernel). Rare; SDF. [OBL]. *00-424*

Pyrolaceae

Chimaphila maculata (L.) Pursh (spotted-wintergreen). Occasional; MOF. [NC]. *99-1115*

Ranunculaceae

Aconitum uncinatum L. (southern aconite). Rare; MOF. [NC]. *00-574*

Anemone virginiana L. (thimbleweed). Infrequent; MOF. [FACU]. *02-290*

Clematis virginiana L. (virgin's bower). Occasional; GC, OSW. [FAC]. *01-707*

Ranunculus abortivus L. (small-flowered buttercup). Infrequent; GC. [FACW−]. *00-30*

**R. bulbosus* L. (bulbous buttercup). Occasional; CD, SGM. [UPL]. *00-79*

R. recurvatus Poir. (hooked buttercup). Infrequent; GC, MOF. [FAC+]. *00-92*

Thalictrum pubescens Pursh (tall meadow-rue). Occasional; OSW. [FACW+]. *87-539*

Rhamnaceae

**Rhamnus frangula* L. (alder buckthorn). Rare; MOF. [NC]. *02-44*

Rosaceae

Agrimonia parviflora Aiton (southern agrimonia). Rare; OSW. [FACW]. *02-309*

A. rostellata Wallr. (woodland agrimonia). Occasional; MOF. [FACU]. *01-611*

Amelanchier arborea (Michx. f.) Fern. (common serviceberry). Occasional; MOF. [FAC−]. *00-758*

Crataegus coccinea L. (scarlet hawthorn). Rare; MOF. [NC]. *00-239*

Fragaria virginiana Duchesne (Virginia wild strawberry). Infrequent; CD. [FACU]. *00-63*

Geum canadense Jacq. (white avens). Occasional; MOF. [FACU+]. *01-603*

Potentilla canadensis L. (Canada cinquefoil). Abundant; CD. [NC]. *02-277*

P. simplex Michx. (common cinquefoil). Occasional; MOF. [FACU−]. *00-142*

Prunus serotina Ehrh. (wild black cherry). Frequent; MOF. [FACU]. *99-1125*

**Rosa multiflora* Thunb. ex Murr. (multiflora rose). Occasional; GC, OSW, MOF. [FACU]. *01-602*

Rubus allegheniensis Porter (common blackberry). Frequent; GC, OSW, MOF. [FACU−]. *00-426*

R. hispidus L. (swamp dewberry). Abundant; OSW. [FACW]. *00-140*

R. occidentalis L. (black raspberry). Infrequent; MOF. [NC]. *02-339*

Spiraea tomentosa L. (pink steeplebush). Frequent; SGM, [FACW−]. *87-539*

Rubiaceae

Cephalanthus occidentalis L. (buttonbush). Occasional; EM. [OBL]. *99-1011*

Diodia teres Walt. (rough buttonweed). Infrequent; CD. [UPL]. *02-445*

D. virginiana L. (Virginia buttonweed). Frequent; SDF, SGM. [FACW]. *99-1051*

Galium aparine L. (common cleavers). Infrequent; MOF. [FACU]. *02-68*

G. tinctorium L. (marsh bedstraw). Frequent; SGM. [OBL]. *87-526*

G. triflorum Michx. (fragrant bedstraw). Occasional; MOF. [FACU]. *01-604*

Hedyotis caerulea (L.) Hook. (spring bluets). Frequent; CD. [NC]. *02-71*

H. canadensis (Willd.) Fosb. (Canada bluets). Rare; MOF. [NC]. *02-268*

H. purpurea (L.) Torr. & A. Gray (summer bluets). Infrequent; MOF. [NC]. *02-446*

Mitchella repens L. (partridge-berry). Abundant; MOF. [FACU]. *00-139*

Salicaceae

Salix nigra Marsh. (black willow). Occasional; OSW. [FACW+]. *99-1102*

Saxifragaceae

Penthorum sedoides L. (ditch-stonecrop). Infrequent; EM, SGM. [OBL]. *99-1129*

Scrophulariaceae

Agalinis purpurea (L.) Pennell (smooth agalinis). Rare; SGM. [FACW−]. *02-407*

Chelone glabra L. (white turtlehead). Rare; SGM. [OBL]. *97-804*

Gratiola virginiana L. (round-fruited hedge-hyssop). Occasional; EM, SDF. [OBL]. *99-1079*

Lindernia dubia (L.) Pennell var. *dubia* (false pimpernel). Frequent; EM, SDF. [OBL]. *99-1128*

Mimulus alatus Aiton (winged monkey-flower). Occasional; EM, GC. [OBL]. *00-421*

**Veronica arvensis* L. (corn speedwell). Frequent; CD. [NC]. *02-111*

**V. officinalis* L. (common speedwell). Infrequent; CD. [FACU−]. *02-51*

**V. serpyllifolia* L. (thyme-leaved speedwell). Occasional; CD. [FAC+]. *00-60*

Smilacaceae

Smilax glauca Walt. (glaucous greenbrier). Occasional; MOF. [FACU]. *99-1105*

S. rotundifolia L. (common greenbrier). Abundant; OSW, MOF. [FAC]. *01-701*

Solanaceae

Solanum carolinense L. (horse-nettle). Rare; CD. [UPL]. *02-272*

S. nigrum L. var. *virginicum* L. (black nightshade). Rare; CD. [FACU−]. *02-449*

Sparganiaceae

Sparganium americanum Nutt. (American bur-reed). Occasional; EM. [OBL]. *99-1012*

Typhaceae

Typha latifolia L. (common cattail). Frequent; EM. [OBL]. *99-1033*

Urticaceae

Boehmeria cylindrica (L.) Swartz (false nettle). Frequent; GC, OSW. [FACW+]. *01-616*

Pilea pumila (L.) A. Gray (clearweed). Occasional; GC, OSW. [FACW]. *99-1131*

Verbenaceae

Phryma leptostachya L. (lopseed). Infrequent; MOF. [FACU−]. *02-307*

Verbena urticifolia L. (white vervain). Infrequent; MOF. [FACU]. *02-304*

Violaceae

Viola conspersa Reichb. (American dog violet). Infrequent; OSW. [FACW]. *00-78*

V. cucullata Aiton (blue marsh violet). Occasional; OSW. [FACW+]. *00-22*

V. hastata Michx. (Halbard-leaved violet). Occasional; MOF. [UPL]. *00-21*

V. rafinesquii Greene (wild pansy). Frequent; CD. [NC]. *00-32*

V. sororia Willd. (common blue wiolet). Occasional; MOF. [FAC]. *00-22*

Viscaceae

Phoradendron leucarpum (Raf.) Reveal & M.C. Johnston (American mistletoe). Rare, on *Nyssa sylvatica*; MOF. [NC]. *01-722*

Vitaceae

Parthenocissus quinquefolia (L.) Planch. (Virginia creeper). Abundant; MOF. [FACU]. *00-395*

Vitis aestivalis Michx. (summer grape). Frequent; MOF. [FACU]. *02-403*

V. labrusca L. (fox grape). Infrequent; MOF. [FACU]. *00-763*

V. vulpina L. (frost grape). Occasional; MOF. [FAC]. *02-336*

ACKNOWLEDGMENTS

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NOTE

Snow Rollers in Northern Kentucky and Elsewhere: An Unusual Weather Phenomenon.—In February 2003 Northern Kentucky and the Greater Cincinnati area were witness to an unusual weather phenomenon, snow rollers (Eigelbach, K. 2003. Snow rollers a rare sight. Cincinnati Post, 13 February.) This phenomenon is often reported in Antarctica and Alaska but, in Kentucky, snow rollers are rare. In early February 2003 northern Kentucky was still experiencing winter weather. Temperatures had been in the freezing range for a week and snow had fallen several times. On 9 Feb 2003 the temperature reached 36°F and most of the snow remaining on the ground had melted. On 10 Feb 2003 the high only reached 33°F as snow once again fell across the area. By the end of the day there was 3 inches of fresh snow on the ground. On 11 February the high was 37°F and the surface of the snow melted somewhat during the day. This slightly melted surface rapidly refroze as the temperatures dropped below 20°F that evening. This refreezing formed an ice-coated surface necessary for the formation of snow rollers. As a cold front rushed in, it brought with it about 1 inch of snow, which fell onto the refrozen surface of the snow already on the ground. This new snow, still loose, was wet and sticky, sticking to itself better than to the icy surface below it. With wind gusts reaching over 40 mph, the fresh snow was already beginning to roll up by 2300 local time. Strong, gusty winds are needed to start snow rollers. The wind blows loose chunks of snow, which roll across the surface driven by the wind. Snow rollers do not roll up like snowballs. They roll in a nearly straight line for sometimes over 50 feet (observed in Kenton, Kentucky) and look like a short log. Sometimes hollow, these natural rolls show the layers of snow picked up as they form. By the morning of 12 Feb 2003 snow rollers could be seen almost everywhere in the Northern Kentucky/Greater Cincinnati area. Most of them were blown in an east–west direction. The beginnings of trails were usually narrow, less than half a inch wide, and the depth was barely noticeable. With the wind out of the west, the snow was blown or pushed toward the east. As it rolled, it picked up additional snow from the ground, continuing the process until some Northern Kentucky rollers were over 1 foot in diameter. Sizes ranged from an average of 6 inches in diameter in northern Kentucky to 18 inches in diameter to the west near Burlington, Kentucky. There were reports of snow rollers almost 2 feet in diameter in northern Cincinnati, Ohio.

The Northern Kentucky/Greater Cincinnati area (portions of Kentucky, Ohio, and Indiana) was not alone in having snow rollers. Also on 11 Feb 2003 and continuing into the next day, rollers formed in the Macon County area, central Illinois, extending around the towns of Buffalo, Lincoln, Forsyth, Sherman, and Petersburg. One to four inches of snow fell in that area in the morning and, by evening, strong winds were forming snow rollers. The typical size in central Illinois was close to 12 inches as reported on WCIA-TV, Champaign, Illinois. See the National Weather Service web page at http://www.crh.noaa.gov/ilx/events/roller.htm. Snow rollers were also reported to have occurred around the Vigo County Public Library in Terre Haute, Indiana, on 11 Feb 2003. They were reported as forming around Indianapolis, Indiana, by WRTV this February. In January 2001 Greeley, Colorado, had fields of snow rollers, so many that in places they were only a few feet apart in every direction. See http://www.100megsfree4.com/farshores/nsballs.htm. On 18 Dec 2000 snow rollers occurred in Russell County, Kansas, near I-70 and throughout the county. They ranged in size from baseballs to 30-gallon drums. (See next page for figure.) See the Kansas State University web page at http://www.oznet.ksu.edu/dp_wdl/snowroller1.asp.—**Dan Spence,** Department of Physics and Geology, Northern Kentucky University, Highland Heights, Kentucky 41099.

Figure 1. Snow rollers on Northern Kentucky University campus, Highland Heights, Kentucky, 12 Feb 2003. **UPPER:** A typical snow roller just over 7 inches in diameter and with a not quite hollow center. **LOWER:** Typical field of snow rollers, some with hollow centers. In the foreground is an odd snow roller, at first appearing to be reverse rolled and unfinished but most likely an eroded form.

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PART OF A BOOK

Kohn, J.R. 1993. Pinaceae. Pages 32–50 in J.F. Nadel (ed). Flora of the Black Mountains. University of Northwestern South Dakota Press, Utopia, SD.

WORK IN PRESS

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ARTICLES

NOTE