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The genus *Trifolium* (Fabaceae) in Kentucky

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ABSTRACT

The scope and range of the genus *Trifolium* (Fabaceae) were examined for Kentucky. Review of literature and 910 herbarium specimens from 35 herbaria revealed 11 species of clover as part of the state's flora: *T. arvense, T. aureum, T. campestre, T. dubium, T. hybridum, T. incarnatum, T. pratense, T. reflexum, T. repens, T. resupinatum, and T. stoloniferum.* Four species are rejected as a part of the flora: *T. alexandrinum, T. ambiguum, T. hirtum, and T. medium.* Descriptions, illustrations, and distribution maps are provided for each species accepted.

INTRODUCTION

The genus *Trifolium* (true clovers) is a nearly cosmopolitan member of the papilionoid Fabaceae (Leguminosae) that contains 240 to 250 species (Zohary and Heller 1984), though this number, rising as new species are described, may be closer to 300 (Gillett and Cochrane 1973). In the Old World, *Trifolium* is native to the Mediterranean region in southern Europe, Asia Minor, the Middle East, and northern Africa, extending into northern Europe and east to northwestern China; in Africa, the genus occurs through eastern regions to South Africa. In the New World, there is a wide diversity of species in western North America, with fewer species native to eastern portions, Central America, and South America. According to Zohary and Heller (1984), the genus may be subdivided into eight sections, six of which (*Paramesus, Mistyllus, Vesicaria, Chronosemium, Trifolium,* and *Trichocephalum*) are native entirely to the eastern hemisphere; *Lotoidea* is native to both the eastern and western hemispheres; *Involucrarium* is endemic to the western hemisphere. The word "clover" is probably derived from the Dutch "klafer" or the Anglo-Saxon "cloefer," meaning "club," a reference to the three-parted leaf that supposedly resemble the three-lobed club of Hercules (Evans 1957; Haragan 1991).

North America is home to ca. 95 species of *Trifolium,* 65 native, 30 introduced. These numbers are higher than those of Isely (1998), since he was not aware of some of the less frequently encountered introduced species. Kartesz (1999) lists 96 species for North America. Of the native North American species, 43 belong in section *Lotoidea*; of these, six are found east of the Mississippi River; the remaining 37, mainly in the Rocky Mountains and along the Pacific coast. The native species in section *Involucrarium* are all found in western North America. The introduced species, representing all sections of the genus except *Paramesus,* have been imported mainly for agricultural purposes, though some introductions appear to have been inadvertent (Isely 1998).

Clover species have been widely cultivated as forage crops for hundreds, if not thousands of years, and are of great economic importance (Duke 1981). In North America, most of the species cultivated are perennials, among the most commonly grown of which are *T.*

pratense (red clover), *T. repens* (white, Dutch, or Ladino clover), and *T. hybridum* (Alsike clover). Annual species sometimes cultivated include *T. incarnatum* (crimson clover), *T. hirtum* (rose clover), and *T. alexandrinum* (berseem clover). Clovers are used as forage crops, as sources of nectar for honey production (Pellett n.d.), for erosion control, and as nitrogen sources for crop fields and pastures. Menke and Hillenmeyer (1886) considered "clover" (species not specified) to be the most important crop then grown in Kentucky.

There is a considerable body of folklore associated with the clovers (Evans 1957). Four-leaf clovers have long been considered a source of good luck and with having the ability to protect against witchcraft (RDA 1986). Four-leaf clovers are actually leaves with mutations resulting in the proliferation of leaflets, with leaflet numbers ranging anywhere from the more commonly seen 4 to 24 or more (Ford and Claydon 1996; Jaranowski and Broda 1978) or rarely a single leaflet (Atwood 1938). The multifoliolate condition is relatively common throughout *Trifolium*. Also of interest to many are the leaf marking patterns on the leaves of many clover species. These can range from the more commonly encountered V-shaped pattern, or chevron, to various types of dark to light, colored or white patterns (Corkill 1971; Ganders et al. 1980). These marks, although attractive, are very variable within a species; they can be inherited to differing degrees, may sometimes vary according to growing conditions, and provide no information of taxonomic value.

During the last 200 years, beginning with M'Murtrie's *Florula Louisvillensis* (1819), many reports have been published on the flora of Kentucky. In those reports, various accounts of the clovers have appeared. The earliest report of *Trifolium* in the state was of *T. arvense*, *T. pratense*, and *T. repens* (M'Murtrie 1819). In the 20th century, McFarland (1942) reported 9 species, and Braun (1943) reported 5. Wharton and Barbour (1971) mentioned only 1, Meijer (1992) listed 9, and Browne and Athey (1992) and Medley (1993) accepted 11. Most recently, Kartesz (1999) recognized 10 species as part of the Kentucky flora.

The purpose of this paper is to determine which species of *Trifolium* are documented for Kentucky and to clarify the known distribution for each species in the state.

MATERIALS AND METHODS

I examined 910 herbarium specimens from the following herbaria (acronyms from Holmgren et al. 1990): APSC, BEREA, BH, BRIT, CAN, CINC, CM, DAO, DHL, EKY, F, GA, GH, KNK, KY, LLO, LSU, MDKY, MICH, MO, MU, NCU, NY, OKL, OSH, PH, SIU, US, VDB, WIS, WKU, and WVA. In addition, specimens were studied from the herbaria of Cumberland College in Wilmington, Kentucky (cumb), the Kentucky Agricultural Experiment Station in Lexington (kes), and the clover herbarium of the Department of Agriculture, University of Kentucky, Lexington (uk). Distributional data were gathered from herbarium records only; no undocumented reports are included in distribution maps. Unfortunately, specimens in the Athey Herbarium (MEM) were unavailable. Distribution records from books, papers, and theses were not included, and data in other published sources may not coincide with those presented here (e.g., Browne and Athey 1992).

RESULTS

Eleven species of *Trifolium* are documented by herbarium specimens for Kentucky. Of these, nine are introduced and two are native to the state. Three clover species reported for Kentucky in literature could not be documented by specimens and are excluded from the flora. For 13 of the 120 Kentucky counties (Adair, Boyd, Cumberland, Hancock, Henderson, Owsley, Robertson, Scott, Simpson, Taylor, Union, Wayne, and Webster), I saw no clover specimens at all.

TAXONOMIC TREATMENT

Trifolium L., Sp. Pl. 764. 1753.

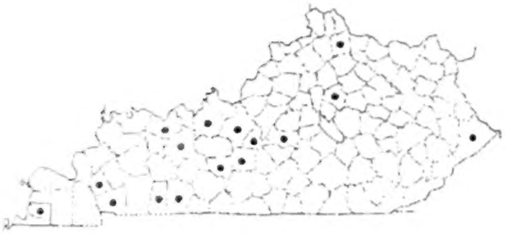
Annual, biennial, or perennial, glabrous to pubescent herbs with a taproot or fibrous roots. Stems simple to much-branched from the base and above. Leaves alternate, palmately trifoliolate to 5–7 foliolate; leaflets toothed; stipules adnate to the petiole. Inflorescences umbelliform, racemose, or capitate, axillary or terminal, long-peduncled to sessile, leafy or not; involucre absent or of small to large free to fused bracts; flowers pedicellate to nearly sessile, with or without bracts; calyx tubular to campanulate, 5-lobed, lobes nearly equal in length or the lower one longer, each lobe entire to toothed; petals free to basally fused, white, pink, red, purple, or yellow, persisting in fruit, the petals clawed and often fused with the staminal column, the upper (banner) broad, oblong to obovate, the lateral pair (wings) narrow, usually longer than the lower pair (keel), which are fused into a boat-shaped structure; stamens diadelphous, filaments dilated below the uniform anthers; ovary sessile or stalked, style curved upward, stigma capitate to curved, ovules 1–12; fruit a straight legume enclosed by the persistent calyx and corolla, dehiscent or indehiscent, seeds 1–3(9), globular to reniform.

KEY TO SPECIES OF *TRIFOLIUM* IN KENTUCKY

1. Plants perennial, stoloniferous, rooting at the nodes; inflorescences held on axillary, upright stems, with or without a pair of bract-like leaves; petals white to pinkish; flowers reflexing with age.
    2. Peduncles 1–2, arising from upright axillary stems with a pair of bract-like leaves; calyx 4–7 mm long, teeth subulate, twice as long as tube . . . . 11. *T. stoloniferum*
    2. Peduncles 1, arising from leaf axil on stolon, without bract-like leaves; calyx 3–5 mm long, teeth triangular-lanceolate, lower about same length as tube . . . . 9. *T. repens*
1. Plants erect or decumbent, not rooting at the nodes.
    3. Petals yellow; banner petal obovate, straight or downcurved; fruit with an obvious stalk inside calyx; petioles mostly shorter than leaflets.
        4. Terminal leaflet sessile or nearly so; stipules nearly as long as to longer than the petiole; fruits 2 times the length of the style; seed ovoid . . . . 2. *T. aureum*
        4. Terminal leaflet stalked; stipules about half as long as the petiole; fruits 3–6 times the length of the style; seeds ellipsoid.
            5. Inflorescences 5–7 mm wide; flowers 2.5–3.5 mm long; terminal leaflet stalk about 1 mm long . . . . 4. *T. dubium*
            5. Inflorescences 7–12 mm wide; flowers 3.5–7 mm long; terminal leaflet stalk 1–3 mm long . . . . 3. *T. campestre*
    3. Petals white, pink, red, or purple; banner petal oblong, upcurved; fruit not stalked or minutely so; petioles mostly longer than leaflets.
        6. Flowers sessile or nearly so, erect to spreading in fruit, in dense globose to elongate heads.
            7. Petals lavender to white; flowers resupinate; calyx with a more densely pubescent region dorsally, becoming inflated in fruit, with obvious reticulating veins . . . . 10. *T. resupinatum*
            7. Petals pink, red, or white; flowers not resupinate; calyx glabrous or with evenly distributed pubescence, not becoming inflated in fruit, veins not obviously reticulating.
                8. Flowers 10–20 mm long; corolla much longer than the calyx; leaflets broadly ovate to obovate; stipules broad, ovate.
                    9. Perennial; heads sessile or nearly so, globose to ovoid; stipules abruptly narrowed into an awn-like tip . . . . 7. *T. pratense*
                    9. Annual; heads stalked, elongate-ovoid to cylindrical; stipules broadly rounded at the tip . . . . 6. *T. incarnatum*
                8. Flowers 5–7 mm long; corolla scarcely longer than to shorter than the calyx; leaflets narrowly oblong to linear-lanceolate; stipules narrowly ovate to oblong . . 1. *T. arvense*
        6. Flowers with pedicels, sharply reflexed in fruit, in umbels.
            10. Annual or biennial; flowers 8–14 mm long; inflorescences 2–4 cm wide; pedicels 4–12 mm long; calyx 6–9 mm long, teeth 2–3 times the length of the tube; leaflets 1–4.5 × 0.5–2 cm; stipules broadly ovate, leaflike . . . . 8. *T. reflexum*
            10. Perennial; flowers 7–10 mm long, inflorescences 1–2.5 cm wide; pedicels 1–5 mm long; calyx 3–4 mm long, teeth 1–2 times the length of the tube; leaflets 1–3.5 × 1–2 cm; stipules narrowly obovate to lanceolate, not leaflike . . . . 5. *T. hybridum*

1. *Trifolium arvense* L., Sp. Pl. 2: 769. 1753. Rabbit-foot clover. (Figure 1)

Annual, upright, 5–40 cm tall. Stems often much-branched, with short appressed to spreading hairs. Leaves petiolate below to nearly sessile above, longest petioles to 15 mm, shorter than the leaflets. Stipules ovate to oblong, tips long attenuate, longer than the



Trifolium arvense L.

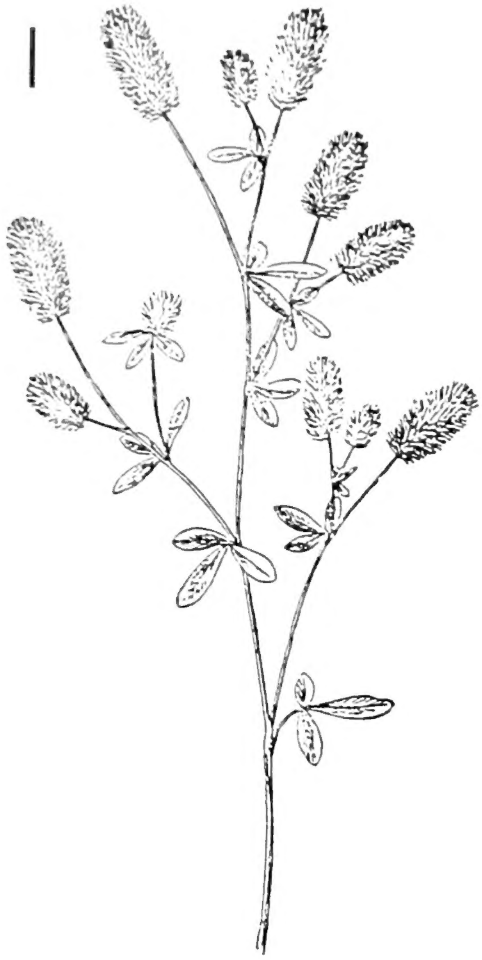


Figure 1. *Trifolium arvense* L. Documented county-distribution in Kentucky; plant (from Besette and Chapman 1992). Bar = 10 mm.

associated petioles. Leaflets 5–20 × 2–4 mm, sessile or nearly so, linear to narrowly lanceolate, base cuneate, apex acute to mucronate and slightly serrate. Inflorescence 8–30 × 8–10 mm, racemose, densely ovoid or cylindrical, on peduncles 5–30 mm, or nearly sessile; flowers 10–150, sessile. Calyx long-hairy, often silvery to pinkish or purplish, tube 1.5–2 mm, teeth subulate, nearly equal, 2.5–5 mm, plumose. Corolla white to pinkish, slightly shorter than the calyx lobes, 4 mm, the standard narrow, oblong, obtuse. Fruit ovoid, 1.3 mm. Seed 1, pale yellow, 0.9–1.3 mm. $2n$ = 14, 16, 28. Flowering in Kentucky in June–July, fruiting August–September.

Native to Europe, northern Africa, and western Asia, rabbit-foot clover is naturalized in many areas of the world and throughout much of North America. Zohary and Heller (1984) recognized two varieties, which differ somewhat in habit and pubescence density. This species was first reported for Kentucky by M'Murtrie (1819). The earliest Kentucky collection I saw was from 1835, Fayette County (*Short s.n.*, CINC, KY).

Trifolium arvense is sometimes cultivated as a winter annual (Henson and Hollowell 1960). It is adapted to infertile, dry, often sandy soil such as that found on roadsides, where is makes an attractive, silvery-pink display when in flower, and rose to buff when in fruit.

This species is sometimes also called hare's foot (M'Murtrie 1819), stone clover, old-field clover, and pussies (Delorit and Gunn 1986; Small 1933).

2. *Trifolium aureum* Pollich, Hist. Pl. Palat. 2: 344. 1777. Hop clover. (Figure 2)

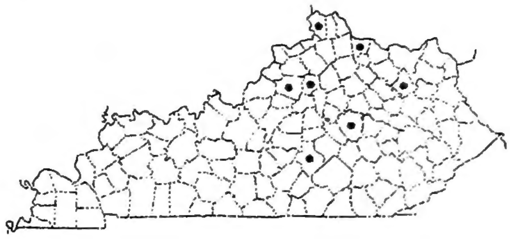
(*T. agrarium* L., a confused name [Dandy 1958])

Annual or biennial, upright, 20–60 cm tall. Stems often much-branched, with short appressed hairs. Leaves petiolate below to short-petiolate above, longest petioles to 12 mm, shorter than the leaflets. Stipules oblong-lanceolate, tips narrowly long-triangular, as long as or longer than the associated petioles, adnate to the petiole for half their length or more. Leaflets 15–25 × 6–8 mm, sessile or essentially so, oblanceolate to obovate or elliptic, base cuneate, apex obtuse to emarginate and mucronate, serrate in the upper half. Inflorescence 10–25 × 12–14 mm, racemose, densely ovoid or cylindrical, with a flat top in age, on peduncles 10–50 mm; flowers 10–40(80), short-pedicellate. Calyx glabrous, tube 1 mm, teeth narrowly triangular to subulate, lower teeth 2–3 times the length of the upper, 1.2–1.8 mm. Corolla bright yellow, turning brown with age, 5–8 mm, the standard broadly obovate, obtuse-emarginate, strongly parallel-veined, especially in age. Fruit oblong, 3–3.5 mm, stalked. Seed 1, pale yellow green to yellow brown, 1–1.2 mm. $2n$ = 14, 16. Flowering in Kentucky in June–July, fruiting August–September.

Native to Europe, hop clover is introduced in eastern and northern North America;

George Washington is known to have ordered seed of this species from Europe in 1786 (Pieters 1920). Zohary and Heller (1984) recognized two subspecies, which differ mainly in the leaf apices and style position. The earliest Kentucky collection I saw was from 1903, Boone County (*Davis s.n.*, kes).

Trifolium aureum has also been called large hop clover, yellow clover, and palmate hop-clover (Gillett and Cochrane 1973; Gleason and Cronquist 1991; Knight 1985b). It is sometimes cultivated (Knight 1985b).



Trifolium aureum **Pollich**

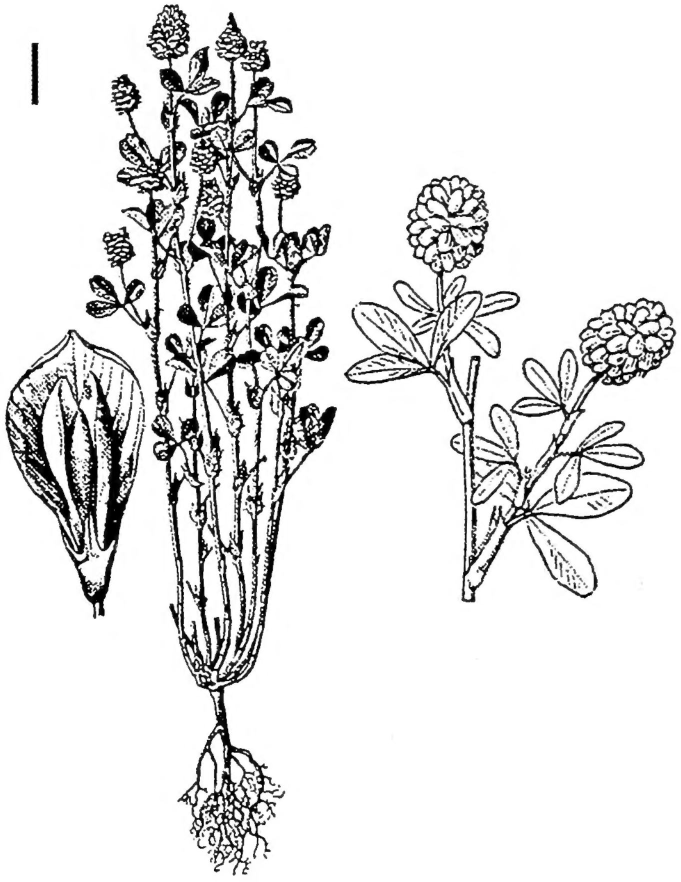


Figure 2. *Trifolium aureum* Pollich. Documented county-distribution in Kentucky; plant (from Cost 1901 [right figure] and Hegi 1923 [left figures]). Bar = 20 mm (whole plant), 10 mm (branch), 2 mm (flower).

3. *Trifolium campestre* Schreb. in Sturm, Deutsch. Fl. Abt. 1, Band 4, Heft 16, t. 253. 1804. Low hop clover. (Figure 3)

(*T. procumbens* L., a confused name [Dandy 1958])

Annual, upright to ascending (rarely prostrate), 5–40 cm tall. Stems often much-branched, with short appressed hairs to nearly glabrous. Leaves pinnate, long-petiolate below to short-petiolate above, longest petioles to 1.5 times as long as the leaflets. Stipules ovate, tips acute to somewhat attenuate, shorter than the associated petioles. Leaflets 4–16 × 4–8 mm, oblong-obovate, base cuneate, apex truncate to emarginate, slightly serrate in the upper half, the terminal leaflet on a 1–3 mm long stalk, lateral leaflets nearly sessile. Inflorescence 7–15 × 7–10 mm, racemose, densely globose to ovoid or cylindrical, on peduncles as long as or shorter than subtending leaves; flowers (10)20–40(50), short-pedicellate. Calyx glabrous to slightly pubescent, tube 0.5–1 mm, teeth narrowly triangular to subulate, lower teeth 2–3 times the length of the upper, 0.6–1.3 mm, each tooth often tipped with 1–2 stiff hairs. Corolla pale to bright yellow, 3.5–6 mm, the standard obovate, with a slightly toothed margin, emarginate, more or less enveloping the wing and keel petals, strongly parallel-veined, especially in age. Fruit oblong, stalked, 2–2.5 mm. Seed 1, shiny yellow, 1–1.5 mm. 2*n* = 14. Flowering in Kentucky in April–June, fruiting June–August.

Native to Europe and widely introduced elsewhere, *Trifolium campestre* is widely distributed in North America, often being found along roadsides, in lawns, and in other disturbed places. Haragan (1991) considers this species a weed in Kentucky. The earliest Kentucky collection I saw was from 1882, Jessamine County (*Peter s.n.*, KY). This species is also called hop clover, pinnate hop clover, and small hop clover (Gillett 1985; Gleason and Cronquist 1991; Knight 1985b).

Low hop clover and especially least hop clover (the next species) are often confused with *Medicago lupulina* L. (black medic), a commonly encountered annual or biennial, prostrate to ascending species. It differs from these clovers by its usually obviously toothed stipules, deciduous corolla, and reniform, shiny black fruits.

4. *Trifolium dubium* Sibth., Fl. Oxon. 231. 1794. Least hop clover. (Figure 4)

Annual, upright, 5–40 cm tall. Stems simple or branched, glabrous to slightly hairy. Leaves

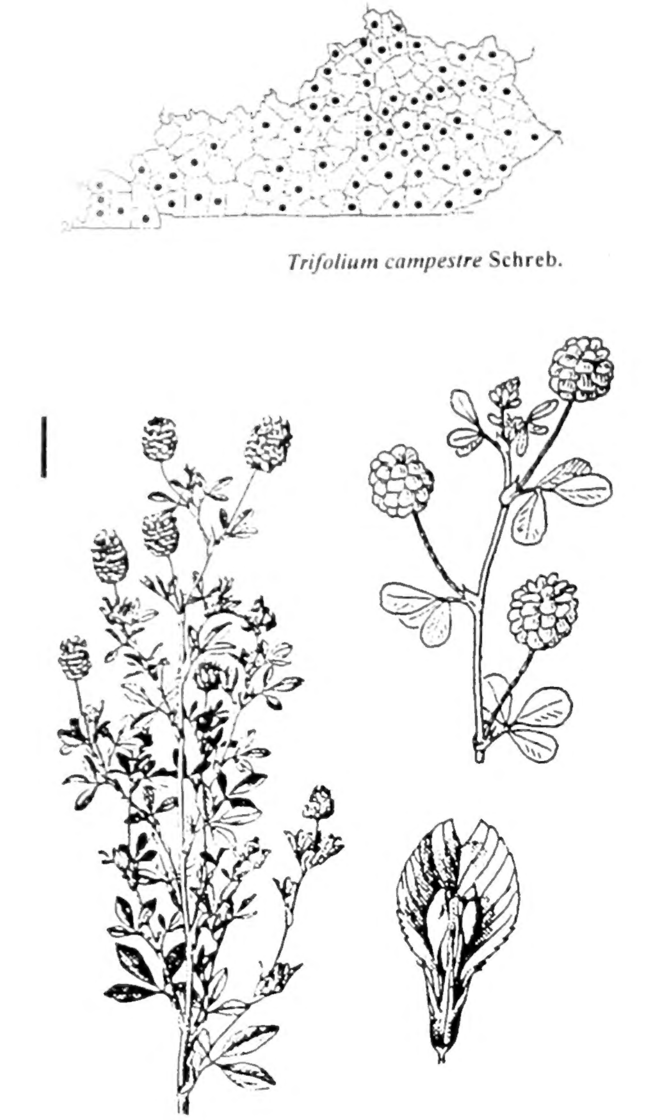


Figure 3. *Trifolium campestre* Schreb. Documented county-distribution in Kentucky; plant (from Cost 1901 [upper right figure] and Hegi 1923 [lower right and left figures]). Bar = 15 mm (whole plant), 10 mm (branch), 2 mm (flower).

pinnate, petiolate below to nearly sessile above, longest petioles to 15 mm, mostly shorter than the leaflets. Stipules ovate, tips acute, slightly adnate to and shorter than the associated petioles, 3–5 mm. Leaflets 5–15 × 4–7 mm, terminal stalked, lateral nearly sessile, obovate, base cuneate, apex rounded to slightly emarginate and slightly serrate. Inflorescence 5–10 × 6–8 mm, racemose, loosely ovoid to obovoid, on peduncles much longer than associated leaves; flowers 3–20, pedicels short, reflexing dramatically with age. Calyx glabrous, tube 0.5–0.8 mm, teeth subulate, lower about twice as long as upper. Corolla pale yellow, 3–4 mm, the standard narrow, oblong, obtuse. Fruit ovoid, nearly sessile, 1.5–2 mm. Seed 1 (rarely 2), shiny tan to dark brown, 1–1.5 mm. $2n = 16, 28$. Flowering in Kentucky in May–June, fruiting July–August.

Figure 4. *Trifolium dubium* Sibth. Documented county-distribution in Kentucky; plant (from Cost 1901 [upper figures] and Hegi 1923 [lower figure]). Bar = 20 mm (whole plant), 10 mm (branch), 4 mm (flower).

Least hop clover is native to Europe and is now introduced throughout the world. It is widely distributed in North America. It is sometimes cultivated as a pasture plant (Delorit and Gunn 1986). *Trifolium dubium* was reported as new to Kentucky by McFarland (1942). Mohlenbrock et al. (1966) again reported the species, but I could not locate the specimen cited in that paper. The species was also reported for Henry County in an unpublished thesis (Gentry 1963), but again the voucher could not be located. Medley (1993) accepted only reports from Lyon, Trigg, and

Rockcastle counties. The earliest Kentucky collection I saw was from 1855, without locality (*C.W. Short s.n.*, PH).

Trifolium dubium is also called little hop clover (Gillett and Cochrane 1973; Gleason and Cronquist 1991), small hop clover (Delorit and Gunn 1986; Isely 1998) and shamrock (Small 1933). It is often confused with *T. campestre,* but can be distinguished from it by the smaller inflorescences with fewer flowers; its standard is not striate or only faintly so, whereas that of *T. campestre* is strongly striate. It is also commonly confused with *Medicago lupulina* L. (black medic), but can be distinguished as described in the entry for *T. campestre*; more records for little hop clover identified as black medic may lurk in herbaria. *Trifolium dubium* is thought by some to be the "shamrock" of Irish folklore, but others claim that the shamrock may be one of several species of *Trifolium, Medicago,* or *Oxalis* (Colgan 1896; Everett 1971; Nelson 1991).

5. *Trifolium hybridum* L., Sp. Pl. 2: 766. 1753. Alsike clover. (Figure 5)

Perennial, upright to ascending, 15–60(80) cm tall. Stems often much-branched, nearly glabrous, often somewhat fleshy. Leaves petiolate, longest petioles to 80 (sometimes even 100) mm, longer than the leaflets, gradually reduced upward. Stipules obovate to lanceolate, tips long attenuate, 10–30 cm, adnate to petioles for about one-third their length. Leaflets 10–35 × 10–20 mm, sessile or nearly so, ovate to elliptical or rhombic, base cuneate, apex rounded to slightly emarginate, serrate. Inflorescence 10–25 mm broad, globose, short-racemose to nearly umbellate, on peduncles 20–80 mm; flowers 20–80; pedicels 1–5 mm, reflexing with age. Calyx glabrous except in the U-shaped sinuses, tube 1–2 mm, teeth subulate, nearly equal, as long as or longer than the tube. Corolla white and pink, 6–11 mm, the standard ovate-oblong, obtuse, sometimes emarginate. Fruit oblong, 3–4 mm. Seeds 2–4, mottled yellow brown, red brown, to nearly black, 1–1.3 mm. $2n = 16$. Flowering in Kentucky in May–July, fruiting July–September.

Alsike clover is native to Europe, probably in the Mediterranean region. It is introduced throughout temperate regions worldwide, and is often cultivated. The species, also called Alsatian clover and Swedish clover (Delorit and Gunn 1986; Small 1933), was apparently first cultivated in Sweden, and first cultivated in England about 1832 (Taylor 1975). It was first brought to the United States about 1839 (Taylor 1975). The earliest Kentucky collection I saw was from 1895, Rockcastle County (*n.c.*, CINC).

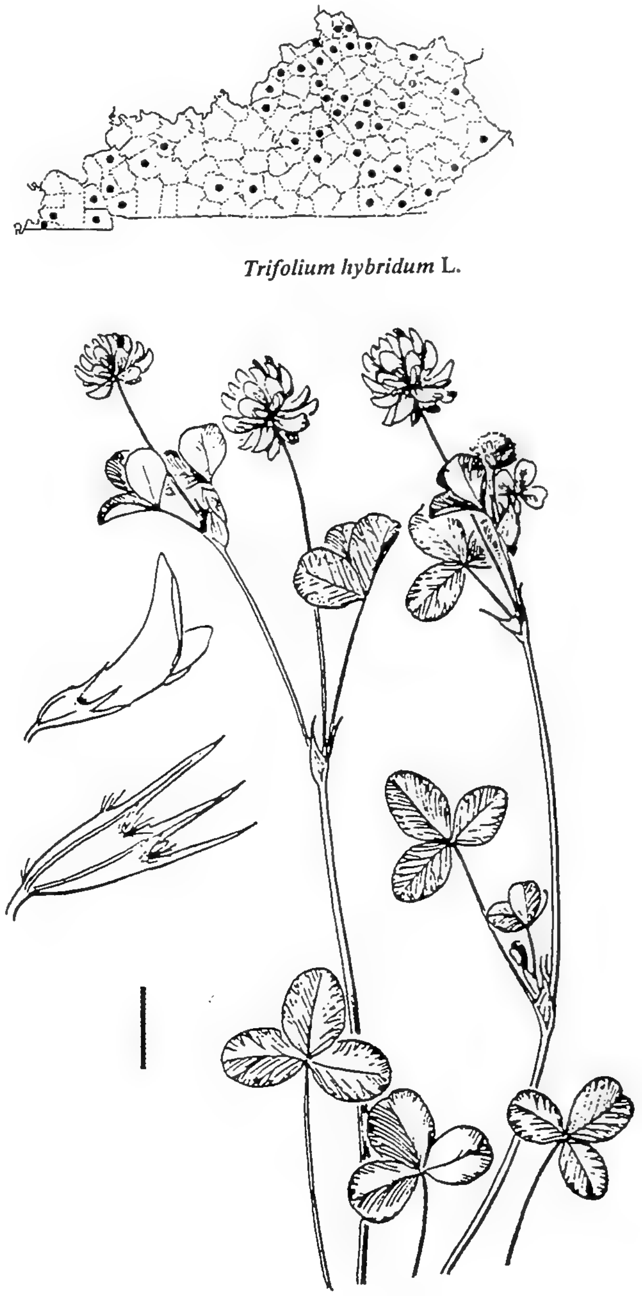


Figure 5. *Trifolium hybridum* L. Documented county-distribution in Kentucky; plant (from Hermann 1966). Bar = 20 mm (whole plant), 5 mm (flower), 1.5 mm (calyx).

Trifolium hybridum may cause dermatitis in sensitive humans (Hardin and Arena 1974). Alsike clover is said to cause photosensitivity and biliary fibrosis in horses (Fisher 1995), though the connection between these diseases and the clover is not conclusive (Nation 1989).

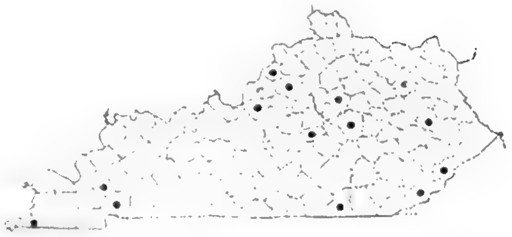
Trifolium nigrescens Viv. (ball clover, a

Mediterranean species) is found with increasing frequency in southeastern United States (Isely 1990, 1998), and has been documented from numerous sites in Tennessee. It is possible that this species will be encountered in the southern tier of Kentucky counties, especially since it can be cultivated in the state (Taylor and Sigafus 1984). Ball clover is an annual, prostrate to ascending, glabrous to glabrescent species, which can be distinguished from Alsike clover by its habit, as well as by V-shaped sinuses between the calyx lobes (U-shaped in *T. hybridum*), white to cream or yellow-white (rarely pale pinkish) corolla (generally deep pink in *T. hybridum*), and stipules with sharply recurved, black to dark maroon, subulate tips (straight, green tips in *T. hybridum*).

6. *Trifolium incarnatum* L., Sp. Pl. 2: 769. 1753. Crimson clover. (Figure 6)

Annual, upright, 20–90 cm tall, hairy throughout. Stems simple to sparingly branched below. Leaves long-petiolate below to nearly sessile above, longest petioles 4–5 times the length of the leaflets. Stipules broadly ovate to oblong, sheathing the stem at the base, white to pale green with dark green to red purple veins below, tips toothed and rimmed with dark red purple or green. Leaflets 10–30(40) × 10–20(30) mm, sessile or nearly so, broadly ovate-obovate to orbicular, base broadly cuneate, apex obtuse to emarginate. Inflorescence 20–60 × 10–20 mm, spicate, densely cylindrical, peduncles 10–60 mm; flowers many, sessile or nearly so. Calyx long-hairy, tube 3–5 mm, teeth subulate, nearly equal, 1–2 times as long as the tube. Corolla crimson, rarely white or pink, longer than the calyx lobes, 10–17 mm, the standard linear-oblong to elliptical, acute. Fruit sessile, oblong, 3–4 mm. Seed 1, buff to brown, 1.9–2.3 mm. $2n = 14$. Flowering in Kentucky in April–May, fruiting June–July.

Crimson clover (also called Italian clover [Small 1933] and many other common names [Knight 1985a; Nourse 1894]), is native to southern and western Europe and widely naturalized in other areas. The species has been cultivated since the 1700s in Europe and was introduced into the United States in 1818 (Knight 1985a). Crimson clover is used extensively as a ground cover in crop rotations, for green manure, and as a nitrogen-fixing plant in fields (Taylor and Sigafus 1984); it is also used an annual hay crop (Nourse 1894). It is occasionally cultivated in Kentucky (Garman 1902; Taylor 1986; Taylor and Sigafus 1984). The earliest Kentucky collection I saw was from 1934, Jefferson County (*Bishop & Bishop s.n.*, DHL).

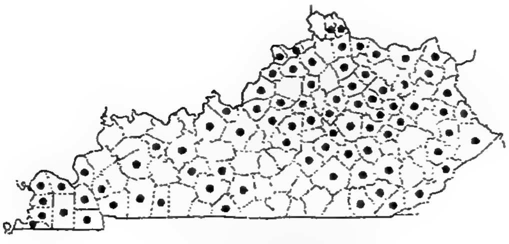


Trifolium incarnatum L.

Figure 6. *Trifolium incarnatum* L. Documented county-distribution in Kentucky; plant (from Hegi 1923). Bar = 40 mm (whole plant), 10 mm (flower), 5 mm (calyx).

7. *Trifolium pratense* L., Sp. Pl. 2: 768. 1753. Red clover. (Figure 7)

Perennial, ascending to upright, 20–60(100) cm tall. Stems much-branched, with appressed to spreading hairs or glabrous. Leaves long-petiolate below to nearly sessile above, longest petioles 3–4 times the length of the leaflets. Stipules ovate to lanceolate, 10–30



Trifrolium pratense L.

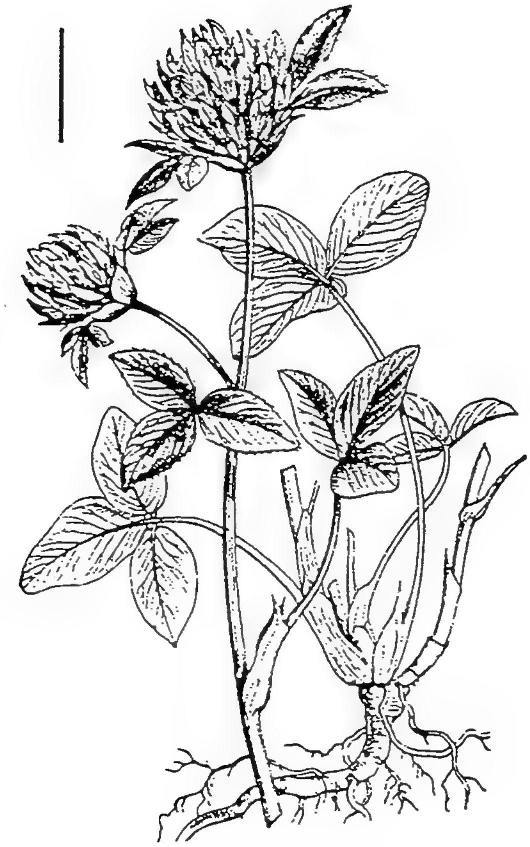


Figure 7. *Trifolium pratense* L. Documented county-distribution in Kentucky; plant (from Besette and Chapman 1992). Bar = 20 mm.

mm, adnate to the petioles for most of their length, the lower portion pale with dark green to red veins tips long mucronate. Leaflets 10–30(50) × 7–15(25) mm, sessile or nearly so, ovate to elliptic or obovate, base broadly cuneate, apex rounded, rarely slightly emarginate, essentially entire. Inflorescence single or in pairs, 10–30 × 10–30 mm, head-like, globose, dense, sessile or on peduncles to about 4 mm, subtended by a pair of bract-like leaves; flowers 40–150, sessile. Calyx hairy, tube 2.5–4 mm, teeth subulate, lowest about as long as the tube, others nearly equal and much shorter than the lowest. Corolla red purple to white or pinkish, longer than the calyx lobes, 11–18 mm, the standard oblong-oblanceolate, emarginate. Fruit ovoid-oblong, 2–3 mm. Seed 1(2), tan to brown, 1.5–2 mm. $2n$ = 14, 28, 56. Flowering in Kentucky in April–October, fruiting June–November.

Trifolium pratense is morphologically very variable, and many binomials have been coined for the various forms; Zohary and Heller (1984) recognized six varieties of the species. Red clover (also called purple clover [Small 1933]) is the grown in more areas of the world than any other species of *Trifolium* (Taylor 1975). It is native to southeastern Europe and Asia Minor (Smith et al. 1985). *Trifolium pratense* has been in cultivation since the 3rd and 4th centuries, probably beginning in Spain, from where it spread to Holland and Lombardy, then to Germany. This species was introduced into England about 1645, from where it was brought to the New World by 1663 (Taylor and Quesenberry 1996). It is a very important forage crop but may also cause bloating in animals overeating its young growth; a diet high in red clover may cause infertility in sheep (Taylor and Quesenberry 1996).

Red clover has been cultivated in Kentucky since at least 1803 (Fergus 1931; Taylor et al. 1997a), and is probably naturalized in every county; Fergus (1931) indicated that red clover was cultivated in every county in Kentucky. M'Murtrie (1819) reported red clover in the Louisville area as early as 1819. The earliest Kentucky collection I saw was from 1892, Fayette County (*Terrill s.n.*, kes). *Trifolium pratense* has been described as a "ubiquitist," which may occur in practically any plant community (Merkenschlager 1934). Red clover has been used in revegetation of strip mine coal spoil fields in western Kentucky (Powell et al. 1980). It is the state flower of Vermont.

Red clover may be used for tea or as an ingredient in herbal cough syrup (Coon 1980; Gibbons 1962), to flavor vinegar (Coon 1980), and as a salve to treat eye and skin diseases (RDA 1984). There are even claims that red clover can be used in cancer treatments (Duke 1985; Ritchason 1995). The young growth can be cooked as a vegetable (Coon 1980). Dried flower heads have been powdered and used in breads during times of famine (Millspaugh 1974).

Trifolium medium (zigzag clover) is a similar perennial species sometimes cultivated in Kentucky (see Excluded Species). It differs

Trifolium reflexum L.

Figure 8. *Trifolium reflexum* L. Documented county-distribution in Kentucky; plant (from Isely 1951). Bar = 20 mm (whole plant), 3 mm (flower).

from *T. pratense* by its peduncled inflorescences, narrowly elliptical leaflets, and rhizomatous nature. *Trifolium hirtum* (rose clover), an annual species resembling red clover, has been reported from nearby states and is occasionally cultivated in Kentucky (see Excluded Species).

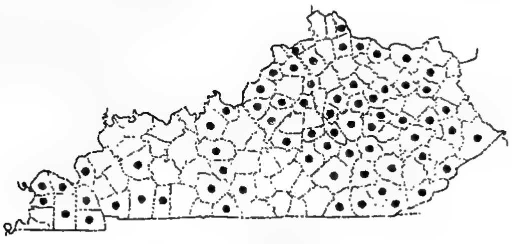
8. *Trifolium reflexum* L., Sp. Pl. 2: 766. 1753. Buffalo clover. (Figure 8)

Annual to biennial, ascending-upright, 20–50 cm tall. Stems simple to branched from the base, densely pubescent to glabrous. Leaves petiolate, gradually reduced upward, longest petioles 3–4 times the lengths of the leaflets. Stipules broadly ovate, leaflike, tips long acuminate, entire to serrate. Leaflets 10–30(45) × 6–20(25) mm, sessile or nearly so, ovate to obovate, base cuneate, apex acute to broadly rounded, serrate. Inflorescence 20–35(40) mm wide, umbellate, nearly spherical in flower, on peduncles 20–60(80) mm; flowers 10–40; pedicels 4–8 mm, reflexing dramatically and elongating to 7–12(15) mm in fruit. Calyx hairy to glabrous, tube 1–1.5 mm, teeth linear, nearly equal, 3–7 mm, with broad, U-shaped sinuses between. Corolla deep pink to white, longer than the calyx lobes, 8–14 mm, the standard oblong to elliptic, obtuse, often slightly emarginate. Fruit ovoid to oblong, 3–5 mm, slightly stalked. Seeds (1)2–4, pale yellow, 1–1.5 mm. $2n = 16$. Flowering in Kentucky in May, fruiting June.

Buffalo clover is native to eastern North America from Virginia and the Carolinas south into Florida, west to central Texas, north to eastern Kansas, Nebraska, and Iowa, and east to Ohio; there is also an old record from eastern Pennsylvania. The earliest Kentucky collection I saw was from 1835, Fayette County (*Short s.n.*, GH); the most recent collection was from 1990, Trigg County (*Chester et al. 90-210*, APSC). This species is becoming very rare in Kentucky (Taylor and Campbell 1989) and is listed as endangered in the state (KSNPC 1996); four extant "occurrences" are recorded by the Kentucky State Nature Preserves Commission (D.L. White, KSNPC, pers. comm., 19 Jan 2000).

According to Taylor et al. (1994), buffalo clover is autogamously self pollinated. Some authors have recognized two varieties, based on pubescence differences, but this character is variable and probably clinal in nature, with the more glabrous forms in the northeastern part of the range of the species. Glabrous and pubescent forms may grow intermingled in some mid-south populations, with the most densely pubescent populations occurring in the deep south and the western portion of the range. The species was rediscovered in Ohio in 1990 at a site that had burned the previous fall (Vincent 1991), but there have been no further fires, and it has not reappeared there since. Populations of this species often reappear in sites after a burn, heavy logging, or some equally severe disturbance (pers. obs.).

Trifolium virginicum Small ex Small & Vail (Kate's Mountain clover) is a similar species found on exposed shale barrens from southwestern Pennsylvania south through West Virginia to the Shenandoah Valley of Virginia



Trifolium repens L.

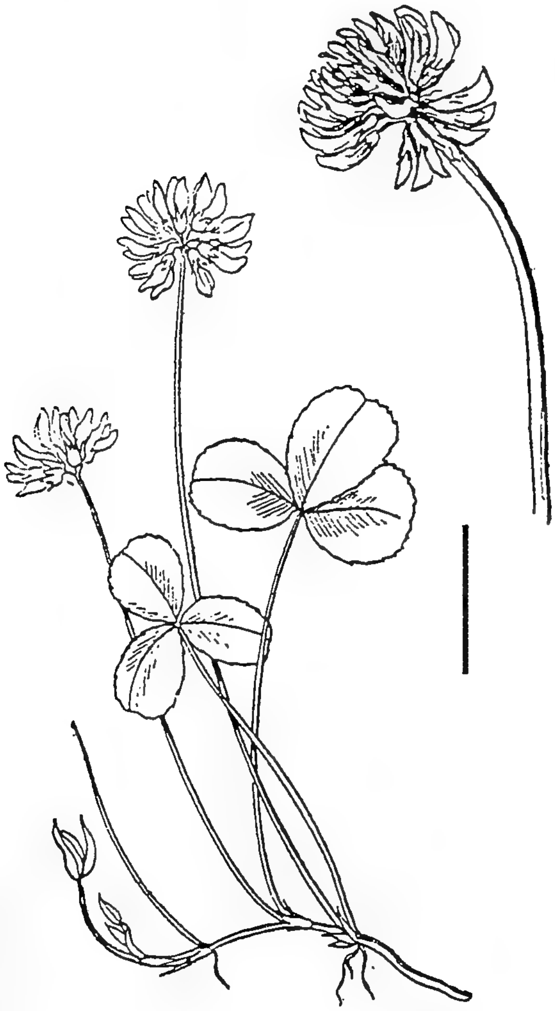


Figure 9. *Trifolium repens* L. Documented county-distribution in Kentucky; plant (from Besette and Chapman 1992). Bar = 20 mm (whole plant), 15 mm (inflorescence).

(Linscott 1994). It is a perennial species, with a rosette of leaves with narrowly elliptical leaflets; the corolla is white. If suitable habitat were found in eastern Kentucky, this species might be found there.

9. *Trifolium repens* L., Sp. Pl. 2: 767. 1753. White clover. (Figure 9)

Perennial, stoloniferous to rhizomatous, rooting at the nodes, 10–30 cm tall. Stems much-branched, glabrous to sparsely hairy. Leaves petiolate, petioles 10–200 mm. Stipules thin and membranous, whitish to brownish, often with darker reddish to greenish veins, ovate-lanceolate, fused into a tube, tips short-attenuate, 8–15 mm. Leaflets 6–30 × 10–25 mm, sessile or nearly so, broadly elliptic to ovate, base broadly cuneate, apex obtuse to emarginate or obcordate, serrate. Inflorescence 15–35 mm broad, umbellate to short-racemose, nearly globose, on peduncles as long as or longer than the associated leaves, arising from leaf axils on the stolons; flowers 20–50(100); pedicels reflexing dramatically with age. Calyx glabrous, often whitish with a purplish to green apex, tube 1.8–3 mm, teeth triangular-lanceolate, unequal, upper shorter than the tube, lower about as long as tube, sinus sharply V-shaped. Corolla white to pinkish, 7–12 mm, the standard elliptic-obovate, obtuse. Fruit linear-oblong, 3–5 mm. Seeds 3–4, yellowish tan to brown, 0.9–1.5 mm. $2n$ = 16, 28, 32, 48, 64. Flowering in Kentucky in March–November, fruiting June–November.

White clover (also called Dutch clover and Ladino clover) may very well be the most important temperate pasture plant (Baker and Williams 1987). It was introduced so early and was so widely grown in North America that it was known to Native Americans as "White man's foot grass" (Strickland 1801); its cultivation may have begun in the early 1700s, and it was widespread by the middle of that century (Isely 1998). Piper (1924) considered white clover "the most important perennial pasture plant in North America." The species is widely grown in Kentucky (Rice et al. 1982) and was the earliest clover species cultivated in the state (Carrier and Bort 1916). M'Murtrie (1819) reported this species from the Louisville area. The earliest known Kentucky collection I saw was from 1890, Fayette County (*Garman s.n.*, kes). The species is undoubtedly to be found in every Kentucky county.

Trifolium repens is extremely morphologically plastic, and varies greatly in size of both leaves and flowers depending upon environmental conditions (Gillett and Cochrane 1973). Zohary and Heller (1984) recognized nine intergrading varieties. Most North American specimens appear to be *T. repens* var. *repens*. A recent monograph on the species covers in great detail many aspects of its taxonomy, morphology, and cultivation (Baker and Williams 1987).

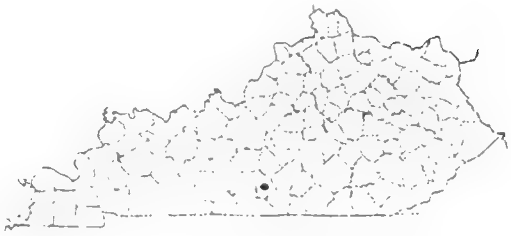
White clover may have some medicinal uses, although human ingestion of powdered fresh flower heads resulted in "a sensation of fullness and congestion of the salivary glands with pain, and . . . mump-like pain . . . followed by copious flow of saliva" (Millspaugh 1974).

A similar species is *T. calcaricum* Collins & Wieboldt, which differs from white clover in its terminal inflorescences. It is native to the cedar glades of central Tennessee and southwestern Virginia (Collins and Wieboldt 1992). If similar cedar glade habitat exists in southeastern Kentucky, it is possible that this species could be found in the state; it is found in Lee County, Virginia, within 10 miles of the Kentucky state line.

10. *Trifolium resupinatum* L., Sp. Pl. 2: 771. 1753. Persian clover. (Figure 10)

Annual, procumbent to ascending or upright, 10–60 cm tall. Stems often much-branched, glabrous or nearly so. Leaves petiolate below to nearly sessile above, longest petioles to 4–5 times the length of the leaflets. Stipules lanceolate to lanceolate-ovate, tubular at the base, tips long attenuate, shorter than the associated petioles. Leaflets 5–20(30) × 2–4 mm, sessile or nearly so, obovate, elliptic to lanceolate, or rhombic, serrate, base cuneate, apex rounded to acute. Inflorescence 8–15 mm broad, capitate, densely hemispherical, on peduncles 20–50 mm; flowers 6–20, short-petiolate to sessile. Calyx glabrous except for a dorsal band of hairs, whitish to pale green with a dark basal band, tube 1.5–2 mm, teeth subulate, unequal, shorter than the tube, often dark green; calyx becoming inflated and enclosing the fruit at maturity, the veins obviously reticulating. Corolla resupinate, lavender to pink or rarely white, 4–9 mm, the standard oblong, emarginate. Fruiting head globose, looking star-like. Fruit ovoid-lenticular, 1.7–2.3 mm. Seed 1, yellow to tan or purple brown, 1.2–2 mm. $2n = 14, 16, 32$. Flowering in Kentucky in May–June, fruiting June–July.

The resupinate (inverted, with the standard below and the keel above) corolla and inflated fruiting calyx makes *T. resupinatum* easy to distinguish from other clovers. The presence of Persian clover in Kentucky was first reported by McFarland (1942), whose report was accepted by Browne and Athey (1992) and Medley (1993). It may be cultivated in the state as a winter annual (Taylor and Sigafus 1984). I located only one Kentucky collection, from 1915, Metcalfe County (*Salmon s.n.*, kes). A report by Browne and Athey (1992) for the Shawnee Hills was rejected by Medley (1993), and I was unable to locate a specimen to verify the report. Widespread in much of the southeastern United States (Isely 1990), this species was recently documented from Ohio (Vincent and Cusick 1998). It is reported from "scattered stations" in northeastern U.S. by Gleason and Cronquist (1991).

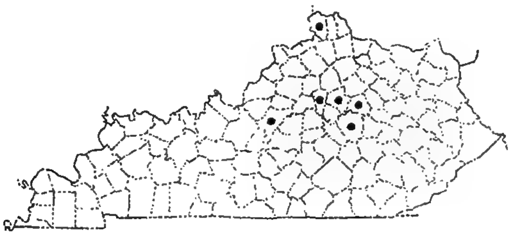


Trifolium resupinatum L.

Figure 10. *Trifolium resupinatum* L. Documented county-distribution in Kentucky; plant (from Hegi 1923). Bar = 20 mm (whole plant), 3 mm (flower and fruiting calyx).

11. *Trifolium stoloniferum* Muhl. ex A. Eaton, Man. Bot. 468. 1818. Running buffalo clover. (Figure 11)

Perennial, stoloniferous, upright flowering branches 10–40 cm tall. Prostrate stems often



Trifolium stoloniferum
Muhl. ex A.Eaton

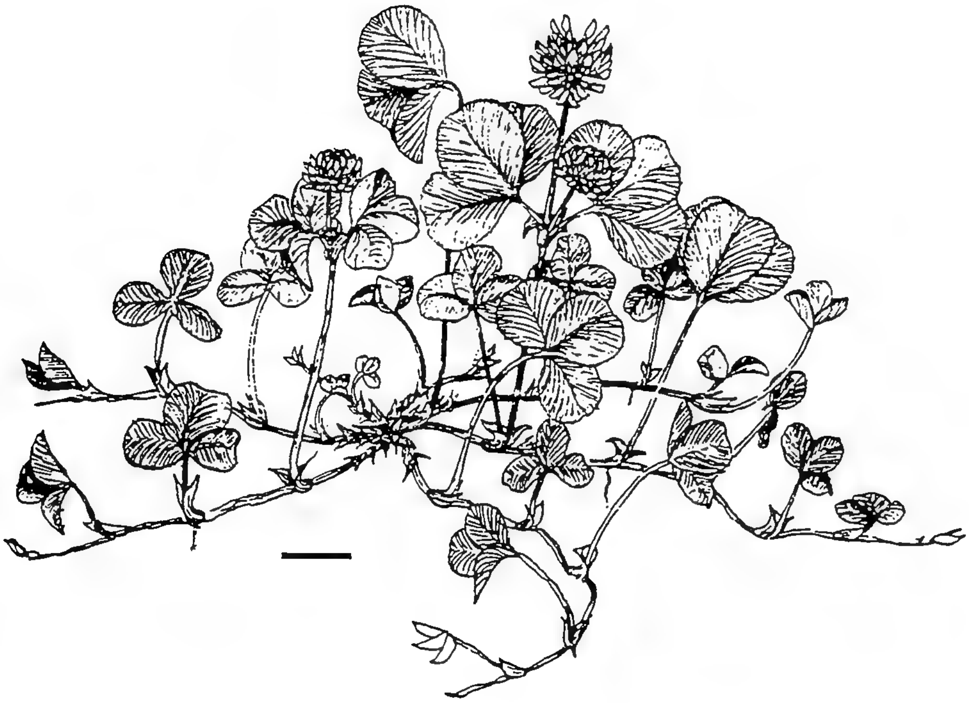


Figure 11. *Trifolium stoloniferum* Muhl. ex A. Eaton. Documented county-distribution in Kentucky; plant (drawn by Ethel Hickey 1995, used with permission). Bar = 20 mm.

little branched, glabrous or nearly so, rooting at the nodes, forming extensive clones. Leaves from stolons long-petiolate, those on the upright flowering stems in a pair, petioles as long as the leaflets or shorter. Stipules of stolons broadly lanceolate, membranous, tips attenuate, shorter than the associated petioles; those of the upright stems leaf-like, ovate-oblong, broadly triangular to attenuate, slightly to much-serrate. Leaflets 10–40 × 8–35 mm, serrate, on petiolules about 1 mm, obovate to obcordate, base broadly cuneate, apex rounded to emarginate. Inflorescence 15–30 mm wide, umbellate, spherical, on peduncles 10–30 mm; flowers 25–45; pedicels 2–8 mm, reflexing dramatically in age. Calyx glabrous or nearly so, tube 1.5–2.5 mm, teeth subulate, nearly equal, about twice the length of the tube. Corolla white, sometimes pinkish with age, 8–14 mm, the standard obovate to oblong, rounded to emarginate. Fruit oblong, 2.5–3 mm. Seeds 1–2, yellow to brown, 1.3–2 mm. $2n$ = 16, 32. Flowering in Kentucky in April–May, fruiting May–June.

In spite of the use of the citation "Muhl., Cat. Pl. Amer. Sept. 67. 1813." for this name (Browne and Athey 1992; Medley 1993; Zohary and Heller 1984), the authorship should be given as "Muhl. ex A. Eaton" since Muhlenberg's (1813) publication of the name was a "nomen nudum" as stated by Merrill and Hu (1949) and Brooks (1983).

Running buffalo clover once ranged widely over middle east-central North America from present-day West Virginia west to Kansas, and from Arkansas north to north-central Ohio (Brooks 1983). Its predominant range was montane West Virginia and the Ohio River drainage in Ohio and south to central Kentucky. It was once found in great stands in

Kentucky (Campbell et al. 1988) and Ohio (Cusick 1989). This species, once thought extinct, was rediscovered in 1983 by Bartgis (1985), and was listed in 1987 by the US Fish and Wildlife Service as an endangered species (Anonymous 1987) under the federal Endangered Species Act. It was thought to be very rare in Kentucky (Taylor and Campbell 1989), and is listed as a threatened species in the state (KSNPC 1996); 69 extant "occurrences" are recorded in the state by the KSNPC (D.L. White, KNSPC, pers. comm. 19 Jan 2000). The earliest Kentucky collection I saw was from 1834, Fayette County (*Peter s.n.*, MICH, NY); the most recent is from 1995, Madison County (*Vincent et al. 6959*, MU).

Taylor et al. (1994) stated that running buffalo clover is an outcrossing species that sets fewer seeds if selfing, but that seed set in selfed plants was still high enough to maintain the species in the wild. They also suggested that habitat loss and competition may contribute more to the decline of the species than inbreeding. Hickey et al. (1991) found that genetic diversity was low among many populations of the species, based on allozyme banding patterns, and that many populations might actually represent clones. Crawford et al. (1998), however, in a study using RAPDs, found that most populations were not single clones, and that even the smallest populations contained unique genetic information.

Running buffalo clover is sometimes confused with *T. repens*, from which it differs by the bract-like pair of leaves below the inflorescence on the upright stems, and by the overall larger size of the former. Another similar species is *T. calcaricum*, which is discussed under the treatment of *T. repens*.

EXCLUDED SPECIES

Trifolium alexandrinum L. Berseem clover

This species was reported from cultivation by Garman (1902) and more recently by Taylor and Sigafus (1984). Its presence in Kentucky outside of cultivation was rejected by Medley (1993). There is a Fayette County specimen (*Garman s.n.*, kes), but it is from cultivation. I saw no specimen of this clover from other than cultivation.

Trifolium ambiguum L. Kura clover

Kura clover can be cultivated in Kentucky and is a very hardy rhizomatous perennial (Taylor 1991a; Taylor et al. 1997b). Isely (1998) and Kartesz (1999) reported *T. ambiguum* as an escape in Ohio, but the reports were based on cultivated material; it is not yet documented that the species will escape in North America. All Kentucky collections I examined were of cultivated material.

Trifolium hirtum L. Rose clover

Rose clover was reported for Kentucky by Isely (1990, 1998) and was provisionally accepted by Medley (1993). Kartesz (1999) accepted the species as part of the state flora. The only Kentucky specimens identified by Isely as *T. hirtum* were at NCU. Of those, all were *T. pratense* except one, a cultivated specimen of rose clover from Jefferson County (*Gunn J150*, NCU). If this species becomes widely cultivated, and since it is possible to grow it in Kentucky (Taylor and Sigafus 1984), it could very well become established in the state.

Trifolium medium L. Zigzag clover

Zigzag clover was reported for Kentucky by Garman (1902) and Linney (1880). I saw no non-cultivated Kentucky specimens of this species, although it is known to be cultivated in the state (Taylor 1991b). Medley (1993) rejected the occurrence of this species in Kentucky. Gleason and Cronquist (1991) reported that *T. medium* occasionally escapes from cultivation in northeastern North America. I have seen specimens from escaped populations in North Carolina, Massachusetts, Maine, and eastern Canada.

Other clover species which are known only from cultivation in Kentucky include *T. vesiculosum* Savi (arrowleaf clover) and *T. subterranean* L. (sub clover) (Taylor and Sigafus 1984). In addition, Dr. Norman Taylor has cultivated many other species in greenhouses and field plots in Lexington.

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The Role of Light in Regulating Dandelion (*Taraxacum officinale*; Asteraceae) Inflorescence Height

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ABSTRACT

This research examined the ecophysiological basis for extension of the stalks (scapes) supporting the inflorescences (heads) of the common turfgrass weed, dandelion (*Taraxacum officinale* Weber). In turf, a statistically significant positive correlation was observed between turfgrass height and height of dandelion heads occurring in it. Dandelion heads tended to extend to the top of the turfgrass canopy only, whereas seedheads extended, on average, an additional 11 cm above that. Excised scape segments taken from scapes at the pre-flowering stage elongated significantly less in the light than in the dark; those taken after flowering elongated the same in the light as in the dark and significantly more than the illuminated pre-flowering scapes segments. In a whole-plant study, pre-flowering scapes grown in a far-red enriched microenvironment elongated significantly more than scapes grown in other light microenvironments. Scape elongation after flowering, however, was not statistically different in any treatment. Pre-flowering scape elongation in dandelion, therefore, appears to be a phytochrome-mediated response, whereas elongation after flowering is not. These results suggest that dandelion scape elongation may be physiologically linked to the height of the turfgrass canopy.

INTRODUCTION

Dandelion (*Taraxacum officinale* Weber) possesses numerous weedy characteristics that make it one of the most common invasive plants of turf in urban areas (Longyear 1918). It is adapted to a wide range of environments, is a long-lived species, reproduces vegetatively from its taproot, and has few natural enemies (Crutchfield and Potter 1995; Mitich 1989; Roberts 1936). Dandelion is also a prodigious seed producer: up to 60,000 seed m^{-2} per season (Roberts 1936). *Taraxacum* species can set seed apomictically, thus ensuring high seed production even under conditions unfavorable for fertilization, such as extreme temperatures, water stress, or lack of pollinators (Munn 1919). Seed dispersal over long distances is assisted by the parachute-like pappus attached to each seed.

Another characteristic contributing to the weedy nature of this species concerns the growth habit of its reproductive stalk (scape). Dandelion inflorescences (heads) often do not extend far enough above the soil surface to be cut by turfgrass mowers. Prior to flowering, dandelion scapes grow straight upwards, but immediately after flowering elongation slows noticeably and the uppermost portion of the scape can become diagravitropic (Clifford and Oxlade 1989). As a result, dandelion heads, for the majority of the time it takes for the seed to mature, are kept low to the ground and below the lawnmower blade (Longyear 1918). During seed maturation the scape rapidly elongates upwards again, lifting the seedhead far above the canopy and into a better position for dispersal of seed by wind (Chao 1947; Longyear 1918). Growth during the pre-flowering and pre-shattering (post-flowering) stages may be partially controlled by hormones (Clifford et al. 1985; Clifford and Oxlade 1989; Oxlade and Clifford 1981).

My research concerns the ecophysiological mechanisms controlling elongation of dandelion scapes. There have been numerous reports on how radiant energy controls the way plants develop and interact with one another (Ballare et al. 1992; Briggs 1996; Holt 1995; Koornneef and Kendrick 1994; Schmitt and Wulff 1993). One of the most important plant molecules involved in the detection of light is phytochrome. Numerous plant photomorphogenic responses are mediated by phytochrome, including those regulating plant height, branching, leaf shape, photoperiodic flowering, photosynthate allocation, and seed germination (Ballare et al. 1988; Ballare et al. 1990; Ballare et al. 1992; Novoplansky 1991; Sanchez 1971; Schmitt and Wulff 1993; Smith 1982; Vierstra 1993).

Phytochrome is a family of photoreceptor molecules containing a photoreversible pigment that can absorb either red (maximal at 666 nm) or far-red (maximal at 730 nm) light. Plants grown completely in the dark synthesize the form of phytochrome (designated P_r) that absorbs red light. Following an exposure to red light the P_r pigment converts to a form (designated P_{fr}) that absorbs far-red light. After an exposure to far-red light the P_{fr} can convert back to P_r in a cyclical process. One of the ways that red:far-red ratios are modified in nature is by the presence of neighboring plant foliage (Ballare et al. 1988; Holmes and Smith 1975; Smith 1994). This is due to the preferential absorption of red light (vs. far-red) by chlorophyll. If a plant is growing by itself in uninterrupted sunlight, the microenvironment will contain more red light than far-red, and there will be relatively more P_{fr} in the plant, while a plant growing in a dense vegetative canopy will be exposed to more far-red light than red and contain relatively more P_r. The physiologically active form of phytochrome is P_{fr}. When present, it induces the synthesis of a cascade of gene products involved in the photomorphogenic traits mentioned above (Smith 1994; Vierstra 1993). Generally, high levels of P_{fr} inhibit elongation of plant cells and tissues. The magnitude of phytochrome-mediated responses is often a function of the $P_{fr}:P_r$ ratio at any given time.

In plants, exposure to lowered red:far-red ratios typically induces an increase in apical elongation (height) at the expense of lateral growth (Ballare et al. 1987, 1990; Schmitt and Wulff 1993; Smith 1982), and is the reason that plants growing beneath a plant canopy are generally taller than in an open field (Holmes and Smith 1975; Solangaarachchi and Harper 1987). Even plants similar in height can have this influence on one another at distances up to 30 cm (Smith et al. 1990). The ecological consequence of this "neighbor effect" is that plants detect the presence of other plants in their vicinity before those plants become competitors for sunlight or pollinators (Ballare et al. 1988, 1991; Holt 1995).

The objectives of my study were to examine the role of light in regulating dandelion scape elongation, and to describe the developmental changes in light sensitivity of the scape during the transition from flowering to seed dispersal.

MATERIALS AND METHODS

Field Observation

Naturally occurring variation in dandelion scape height was evaluated in Louisville, Kentucky, in April–May 1996 and April 1997. Sixty-six randomly selected turfgrass sites were surveyed in 1996; 81 sites in 1997. Survey sites were from public and residential turfgrass areas that were in full sunlight and had not been recently mowed. Measurements taken at each site were height of open inflorescence (from soil level to the bottom of receptacle), height of shattering seedhead (from soil level to bottom of receptacle), and turfgrass canopy height. In both cases, the head was pulled vertically taut while measuring heights. Best-fit regression analysis was performed with these data (Jandel Scientific 1995).

Excised-Scape Study

Dandelion scapes at either the pre-flowering or pre-shattering (post-flowering) stages were collected in May 1996 from a single, uniform turfgrass location on the Bellarmine University campus (Louisville, Kentucky), excised into 1 cm segments, and floated in 100 × 15 mm petri dishes containing a 20 ml sucrose solution (10 g l^{-1}) and 30 μM 3-indoleacetic acid, as described by Chao (1947). It has been determined that indoleacetic acid is necessary to prevent the scape segments from splitting. Only the upper 4 cm of each scape were used for sampling, and segments were evenly distributed into different treatments (dishes).

Dishes containing the scape segments were immediately placed onto a glass shelf in an environmental growth chamber and allowed to grow for 3 days at constant illumination and constant temperature (26°C). Sixteen 160-W fluorescent bulbs provided illumination from above, and two 100-W clear incandescent bulbs provided illumination from below. The photosynthetic photon flux density (PPFD) provided from above was 874 μmol $m^{-2}s^{-1}$; the PPFD from below was 42 μmol $m^{-2}s^{-1}$, both measured by a LI-1800 spectroradiometer (LI-COR Inc).

Transparent, colored cellophane filters cut to the size of the dishes were placed on the bottom to filter the light coming from the incandescent bulbs placed below. Filters transmitted clear, blue, red, or far-red light. Far-red filters were achieved by overlapping blue with red filters. The thickness of the colored filters was adjusted so that each had an equivalent amount of light passing through. Their spectral qualities are described in the next section. Two experimental controls were used: one in which the bottom light was blocked with paper and another in which the dish was completely wrapped in aluminum foil. Each experiment consisted of 12 dishes of excised dandelion segments: six from scapes collected prior to flowering, and six from scapes collected prior to shattering. Each dish held 14 scape segments taken from 14 different plants. The segments in each dish were illuminated the same from above but were treated with one of the five different light treatments from below, while the sixth dish received no light at all. Three days after the start of the experiment the length of each segment was measured and averaged. There were five replicated experiments (blocks), and results were subjected to two-way analysis of variance (Jandel Scientific 1995).

Whole-Plant Study

Dandelion seeds used in this study were collected in May 1995 from a single population in Afton, Minnesota. The seeds were planted into 216 cm^3 plastic containers filled with potting soil (Metro-Mix 510) and grown in the environmental growth chamber with an alternating 14-hr light period (26°C) and 10-hr dark period (20°C). The same growth chamber as described above was used except that six incandescent bulbs (100 W) were used in addition to the fluorescent ones and no illumination was provided from below. This generated a PPFD of 950 μmol m^{-2}s^{-1}. After 2 wk, plants were thinned to three plants per container. Seven weeks after sowing, the plants were vernalized by placing them in a 5°C coldroom and illuminated with fluorescent lights. After 4 mo, the plants were taken out and acclimated.

After acclimation at room temperature for 1 day, single pots were placed individually into the bottom of single transparent plastic cylinders (10-cm diameter). Two windows were cut into the cylinders just above soil level so leaves could be pulled out through the windows and held horizontal. This was to prevent photosynthesis from being affected by the light treatments and to prevent the foliage from interfering with the light microenvironment around the scape. Transparent colored cellophane (described above) was wrapped around the cylinders above the windows extending 7 cm above the soil. Blue, red, and far-red filters were used. As done previously, the thickness of the colored filters was adjusted so that there was an equivalent amount of light passing through each. As experimental controls, clear plastic was wrapped around one cylinder in the same fashion, and opaque black plastic was wrapped around another. The transmission spectra for the filters were determined with the spectroradiometer. Spectral quality (R : FR) of the different filters was calculated as described by Smith (1994). The R : FR ratios were: clear = 1.54, opaque = 1.43, red = 1.48, far-red = 1.37, and blue = 1.36. Although these values are higher than those reported by other researchers (because most of the radiant energy was emitted from fluorescent light bulbs) they are within the range of values known to induce phytochrome-mediated responses (Holmes and Smith 1975; Smith 1994; Weller and Reid 1993). Each replication (block), of which there were six in all, consisted of five cylinders representing these five light treatments.

Cylinders were placed at least 30 cm apart in the growth chamber. The long-day conditions in the chamber induced the plants to flower. Height of the first six dandelion scapes to emerge from each pot was monitored daily, from the first day of flowering until seedhead opening. Heights were measured from soil level to bottom of receptacle. Two-way analysis of variance was used to test for significance (Jandel Scientific 1995).

RESULTS

Field Observation

To illustrate the relationship between dandelion scape height and height of the surrounding canopy, observations were made in dozens of different public and residential turfgrass communities in Louisville in spring 1996 and 1997. Similar results were observed in both years (Figure 1). The height of the turfgrass canopies ranged from 2 to 35 cm; the height of the dandelion heads growing in them ranged from 3 to 32 cm. Generally, the heads

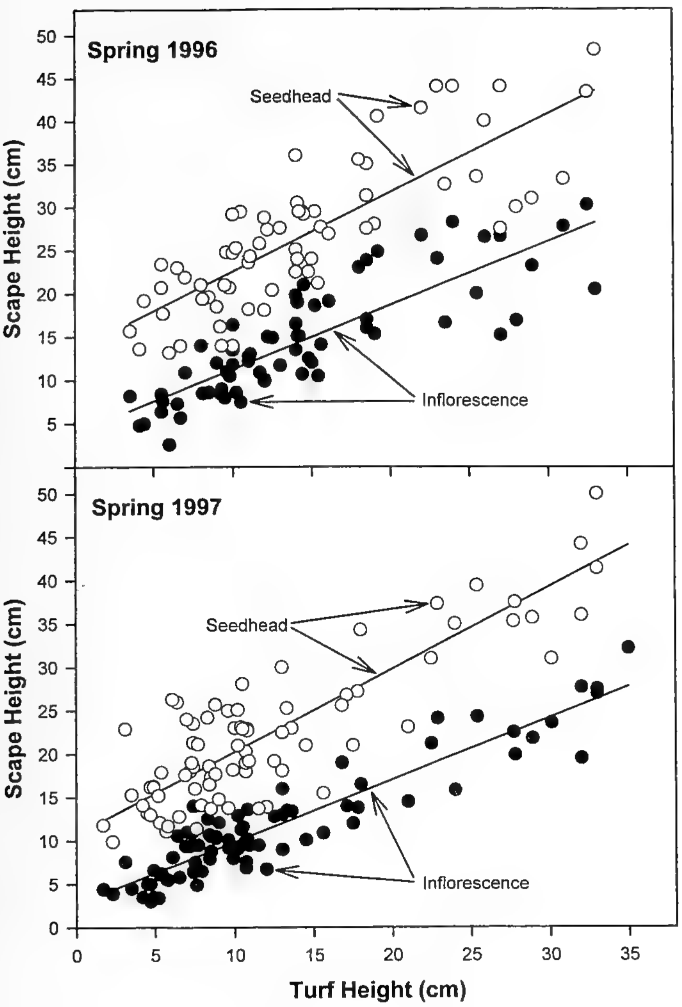

Figure 1. The relationship between turfgrass canopy height and dandelion scape height at various turfgrass sites in Louisville, Kentucky, during spring 1996 (upper) and 1997 (lower). In 1996 (n = 66), inflorescence (head) height was described by Y = 3.884 + 0.737X (r^2 = 0.70), and seedhead height was described by Y = 13.429 + 0.912X (r^2 = 0.65). In 1997 (n = 81) inflorescence (head) height was described by Y = 2.683 + 0.717X (r^2 = 0.86), and seedhead height was described by Y = 10.716 + 0.953X (r^2 = 0.75).

extended only to the top of the turfgrass canopies. Linear regression analysis revealed a statistically significant ($P < 0.001$) correlation between head height and turf height with r^2 values of 0.70 for 1996 and 0.86 for 1997. In 1996, average head height was the same as the average canopy height, whereas in 1997 the average head was 1 cm shorter than the canopy. Regression analysis indicated that heads were slightly taller than the surrounding turf at canopy heights below 15 cm in 1996 (9 cm in 1997). Above that height, dandelion heads tended to be slightly shorter than the canopy. In the tallest turfgrass communities, the dandelion heads averaged 5 cm (1996) and 7 cm (1997) below the canopy.

Seedhead heights, measured at the same locations, ranged from 10 to 54 cm and were significantly taller than the height of the neighboring turfgrass (on average, 12 cm taller in 1996 and 10 cm taller in 1997). Seedhead height was significantly correlated ($P < 0.001$) with the height of the turf canopy with r^2 values of 0.65 for 1996 and 0.75 for 1997. In 1996, the slopes for the head and seedhead regression lines were not statistically different from one another, whereas in 1997 they were ($P < 0.001$).

In this field study, the positive correlation of dandelion scape elongation with height of the neighboring turf canopy suggests that dandelions adjust their scape growth to the vegetative growth of the turfgrass species surrounding it. Since head and seedhead heights were measured at the same time and at the same place, the changes in growth of dandelion scapes prior to flowering versus their growth after flowering were probably due to physiological shifts within the scapes themselves and not to changes in the environment. The other experiments described in this paper were designed to explore the possibility that this regulation of growth is phytochrome mediated. Since scapes at the flowering and seedhead stages appeared to respond to the microenvironment differently, the effect of light at these two developmental stages was also examined.

Excised-Scape Study

Pre-flowering scape segments (that were illuminated) elongated an average of 38%, whereas segments from older scapes, carrying heads that were about to shatter, elongated an average of 50% (Table 1). This difference was statistically significant ($P < 0.001$) and indicates that scape growth, in response to light, shifts as it progresses from one developmental stage to another. The only statistical difference in elongation among the pre-flowering scape segment treatments was for those kept in complete darkness. This experimental control elongated significantly more (15%) than pre-flowering scape segments grown in light. In the dark, however, the pre-flowering scape segments elongated as much as the pre-shattering segments kept in either the light or the dark. No significant differences were observed for pre-shatter scape elongation in any of the

Table 1. Length of pre-flower and pre-shatter dandelion scape segments after 3 d treatment with supplemental light. Scapes were collected in May 1996 in Louisville, Kentucky and excised into 10 mm lengths before treatment. Average of 5 replications, 14 segments per replication (n = 70 segments per treatment). Means followed by the same letter, within a column, are not significantly different ($P < 0.05$) according to the Student-Newman-Keuls test.

Filter color	Pre-flower scape segment length (mm) ± SE	Pre-shatter scape segment length (mm) ± SE
Clear	13.8 ± 0.09 b	14.9 ± 0.05 a
Barrier	13.7 ± 0.06 b	14.6 ± 0.05 a
Blue	13.7 ± 0.07 b	15.1 ± 0.05 a
Red	14.1 ± 0.06 b	15.2 ± 0.05 a
Far-Red	13.7 ± 0.04 b	15.2 ± 0.05 a
Wrapped	15.9 ± 0.02 a	15.0 ± 0.05 a

treatments. All pre-shatter scape segments grew the same whether they were placed in the dark, in the light, or were supplemented with specific wavelengths of light from beneath. This experiment demonstrates that scapes have the same growth potential before flowering as they do afterwards, but that this potential is not realized prior to flowering because of light sensitivity at that stage.

Whole-Plant Study

The flowering head heights in the two control treatments (clear and opaque) were not significantly different from one another and averaged 10.6 cm above soil level, which was 3.6 cm above the top of the filters (Table 2). The blue and red treatments were not statistically different from the clear and opaque treatments. Plants treated with far-red light, however, produced heads that were 23% taller than any of the other treatments or controls (significant at $P < 0.05$). This differential response for far-red light, versus red light, indicates that phytochrome may have a role in regulating head elongation.

It took an average of 7.5 days for heads to develop into shattering seedheads. There were no statistical differences for this time frame among the treatments. During this period the scapes elongated another 6 cm, on average, representing an increase of 52% (Table 2). As with the heads, there were no significant differences in seedhead scape height in the clear, opaque, blue or red treatments. Elongation of the far-red treated scapes, however, was statistically greater. When head height was subtracted from seedhead height, no significant differences were apparent, indicating that post-flowering elongation may not be strongly influenced by the light microenvironment. These results support the field observation that dandelion seedheads extend a fairly uniform distance above the turfgrass canopy regardless of their height at flowering (Figure 1). It also supports the explant study showing that seedhead scape tissue was less sensitive to light than scape tissue at the flowering stage (Table 1).

Another photomorphogenic response that occurred in this study involved the time it took for the plants to flower. It took 13.2 days, from the time the blue-treated plants were placed in the growth chamber, to the time they produced six heads (Table 3). The far-red treatment completed blooming after only 9.5 days, significantly faster ($P < 0.05$) than the blue-treated plants. Accelerated flowering rates are associated with plants pursuing a shade-avoidance strategy, which is generally phytochrome mediated (Smith 1994).

DISCUSSION

Like many weedy-plant species, dandelions show large amounts of phenotypic plasticity

Table 2. Head and seedhead elongation in dandelion plants treated with supplemental light. Prior to treatment, plants were induced to flower under enviornmentally controlled conditions. Average of 6 replications, 6 scapes per replication (n = 36 scapes per treatment). Means followed by the same letter, within a column, are not significantly different ($P < 0.05$) according to the Student-Newman-Keuls test.

Filter color	Head height (cm) ± SE	Seedhead height (cm) ± SE	Difference (cm) ± SE
Clear	10.1 ± 0.46 b	16.0 ± 1.47 b	5.8 ± 1.12 a
Opaque	11.1 ± 0.79 b	16.9 ± 0.82 b	5.8 ± 0.62 a
Blue	10.5 ± 0.62 b	15.0 ± 1.00 bc	4.5 ± 0.81 a
Red	11.0 ± 0.48 b	17.2 ± 1.28 b	6.2 ± 1.40 a
Far-Red	13.1 ± 0.64 a	19.8 ± 1.22 a	6.7 ± 1.19 a

Table 3. Time it took for the first 6 heads to emerge in dandelion plants treated with supplemental light. Prior to treatment, plants were induced to flower under enviornmentally controlled conditions. Average of 6 replications, 6 scapes per replication (n = 36 segments per treatment). Means followed by the same letter, within a column, are not significantly different ($P < 0.05$) according to the Student-Newman-Keuls test.

Filter color	Days to 6th head ± SE
Clear	10.3 ± 1.41 ab
Opaque	12.3 ± 0.49 ab
Blue	13.2 ± 1.08 a
Red	10.3 ± 0.92 ab
Far-Red	9.5 ± 0.76 b

(Clifford and Oxlade 1996). These ecological adaptations are exhibited in their reproductive biology. Dandelion heads require light in order to open, and they must open if they are to set seed (Longyear 1918; Roberts 1936; Tanaka et al. 1987). This means that heads extending to the top of the turfgrass canopy maximize their potential for setting seed. However, the farther above the canopy dandelion heads extend the greater their risk of being separated from the plant by mowing. After flowering, the tight control of scape elongation may not be as important because extension of the seedhead above the canopy surface enhances seed dispersal by wind. This shift in elongation strategy can occur rapidly as both Longyear (1918) and Roberts (1936) observed that dandelions produce viable seed long before seedheads actually shatter.

This research illustrates that control of dandelion scape growth is due to an interaction between the physiological status of the plant and the surrounding microenvironment. In the field, dandelion plants produce heads that just reach the top of the turfgrass canopy. This linkage of dandelion head height to the height of the surrounding turf is maintained in communities ranging from only 2 cm in height up to more than 17 times that. The laboratory studies demonstrate that control over scape elongation is mediated by phytochrome. The far-red treatment (with a red:far-red ratio of 1.37) caused scapes to grow significantly taller than light treatments with higher red: far-red ratios, like clear (1.54), red (1.48), and opaque (1.43). Due to the asymptotic relationship between red:far-red ratios and the amount of P_{fr} in plant tissues (relative to P_{total}), small changes in the quality of light have been found to elicit major physiological changes in plants (Smith 1994). Previous researchers have shown that phytochrome-mediated responses are correlated to relative amount of far-red light up to red:far-red values of 2.00 (Holmes and Smith 1975; Smith 1994; Weller and Reid 1993).

We have measured the red:far-red ratios in natural turfgrass canopy microenvironments to be 1.06, compared to 1.14 in full sun. As dandelion scapes form and elongate, the lower red: far-red ratio caused by the preferential absorption of red light by turf foliage may encourage elongation due to predominance of P_r phytochrome, the form which does not inhibit elongation. When the inflorescence bud approaches the top of the canopy, however, the red:far-red ratio may be high enough (due to predominance of the P_{fr} form of phytochrome) to discourage any further scape elongation and, at the same time, induce head opening.

The photomorphogenic control of scape elongation by phytochrome appears to be developmentally controlled. Whereas all three of these studies indicate that dandelion scapes, up to the time of flowering, are sensitive to light, no evidence was found that scape growth after flowering was affected by light. Thus, major physiological changes must be occurring in this tissue in a relatively short period of time: 7.5 days in this growth-chamber study vs. 9 or 10 days in the field (Longyear 1918). Scape elongation rates between the flowering and shattering stages in the clear-plastic treatment of the whole-plant study averaged more than 8 mm d^{-1}. This growth is rapid enough to carry the head above the turfgrass canopy at a faster rate than the canopy height itself increases. Chao (1947) reported that the majority of this scape growth occurred in the upper third of the scape and involved increases in epidermal cell length, fresh weight, and non-protein nitrogen content, as well as decreases in dry weight, and protein nitrogen content.

An important source of light perception might reside in the dandelion head itself. Tanaka et al. (1987) showed that some type of photoreceptor must occur in the dandelion head as its opening is dependent on sunlight. Since the majority of the scape growth is due to cell elongation in the upper third of the scape (Chao 1947; Oxlade and Clifford 1981) it is possible that a growth regulator (like gibberellin, auxin, or ethylene) is synthesized in the head and moves down to that region (Clifford and Oxlade 1989; Clifford et al. 1985) to modulate tissue growth. This would explain the discrepancy between the excised-scape experiment and the whole-plant experiment. Some factor important to the phytochrome response in dandelion scapes may not have been present in the excised segments.

This research has implications for turfgrass managers interested in reducing the propagation of dandelion by seed. Since the majority of dandelion seed production and dissemination is in the spring (Gray et al. 1973), the simple act of keeping turf taller during the preceding winter months might force dandelion heads to elongate enough in the spring so that a larger percentage of them could be mowed before they set seed. The same scenario might be applied during the second flush of flowering that occurs in the autumn. This paper sets the groundwork for studies of these types of management strategies.

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Distribution and Status of Freshwater Mussels (Bivalvia: Unionoidea) in the Cumberland River Basin Upstream from Cumberland Falls, Kentucky

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ABSTRACT

Freshwater mussels were sampled in the Cumberland River basin upstream from Cumberland Falls in southeastern Kentucky in 1987–1999 to determine their distribution and status. A total of seven species was found at 57 of 434 sampling sites compared to 11 taxa previously reported. *Alasmidonta atropurpurea* and *Anodontoides denigratus*, USFWS- and/or KSNPC-endangered species, are the most abundant taxa and exclusively inhabit tributaries. *Lampsilis ovata* was introduced from below the falls and is extirpated from the basin along with *Toxolasma parvus* and *Villosa lienosa*. We believe that records for *Strophitus undulatus* are based on misidentified *Alasmidonta atropurpurea* and *Anodontoides denigratus*. The Marsh Creek fauna is the richest and most abundant upstream from the falls, and it should be the focus of mussel conservation efforts in the basin.

INTRODUCTION

Despite considerable interest in the freshwater mussels of Kentucky's upper Cumberland River basin (e.g., Miller et al. 1984; Neel and Allen 1964; Schuster et al. 1989; Wilson and Clark 1914), little has been published regarding the fauna upstream from Cumberland Falls. Wilson and Clark (1914) and Neel and Allen (1964) each sampled six sites, all but one in the mainstem, and found a depauperate fauna totaling eight generally uncommon species (Table 1). Recent examination of 14 Cumberland River tributaries revealed mussels only in Marsh Creek and added *Alasmidonta atropurpurea* to the fauna (Call and Parmalee 1981; Harker et al. 1979, 1980; Layzer and Anderson 1992). Museum records for *Toxolasma parvus* and *Villosa lienosa* increase the fauna to 11 species, or ca. 15% of the taxa known from the basin below Cumberland Falls (Cicerello et al. 1991).

The basin above the falls has changed considerably since the work of Wilson and Clark (1914) and Neel and Allen (1964). Communities and infrastructure have expanded, and surface and underground coal mines occur throughout the watershed (Leist et al. 1982). Development has degraded water quality and aquatic communities throughout the basin and downstream from Cumberland Falls (Carter and Jones 1969; Cicerello and Laudermilk 1997; Harker et al. 1979; KDOW 1996). Nonetheless, this area contains many of Kentucky's highest quality streams (KDOW 1997), most of which have not been thoroughly sampled for mussels. We examined streams in the upper Cumberland River basin of Kentucky upstream from Cumberland Falls and museum collections to determine the distribution and status of the mussel fauna.

STUDY AREA

Located in the Appalachian Plateaus Physiographic Province in southeastern Kentucky and Tennessee, the study area encompasses 5120 km^2 of the upper Cumberland River basin in Kentucky extending from Cumberland Falls upstream to the southwest Virginia border (Figure 1). Cumberland Falls is a 17 m high barrier to the upstream movement of aquatic organisms that has receded ca. 72 km from its hypothesized original location near Burnside, Kentucky (McGrain 1966). The Big South Fork Cumberland, Rockcastle, and Laurel rivers and Buck Creek formerly discharged into the river above the falls, but now they enter between its hypothesized original and present locations. The Cumberland River is formed by the confluence of the Poor and Clover forks; it meanders westerly 212 km to the falls. Major tributaries are Marsh, Jellico, Stinking, Straight, and Yellow creeks and Clear and Martins forks. The headwaters of Marsh and Jellico creeks and Clear Fork are in Tennessee. Most streams have moderate to high gradients, clear water, and alternating

Table 1. Mussels collected from the Cumberland River system upstream from Cumberland Falls, following prevailing nomenclature.

1910–1911[1]	1947–1949[2]	1978–1980[3]	1987–1988[4]	This study and museum records
—	*Actinonaias pecterosa*	*A. pectorosa*	—	*A. pectorosa*
—	—	*Alasmidonta atropurpurea*	*A. atropurpurea*	*A. atropurpurea*
Alasmidonta minor	—	*A. viridis*	—	*A. viridis*
Anodontoides ferussacianus	—	—	*A. ferussacianus*	*A. denigratus*
—	*Lampsilis fasciola*	*L. fasciola*	*L. fasciola*	*L. fasciola*
Lampsilis ovata	—	—	—	—
—	*L. o. ventricosa*	*L. ventricosa*	—	*L. cardium*
Strophitis edentulus	—	—	—	—
Unio gibbosus	*Elliptio dilatatus*	*E. dilatatus*	*E. dilatata*	*E. dilatata*
—	—	—	—	*Toxolasma parvus*
—	—	—	—	*Villosa lienosa*

[1] Wilson and Clark (1914); [2] Neel and Allen (1964); [3] Harker et al. (1979, 1980) and Call and Parmalee (1981); [4] Layzer and Anderson (1992).

pools and riffles underlain with substrates ranging from exposed sandstone bedrock to mixed sand and silt. Mean annual discharge and 7-day 10-year low flow at Cumberland Falls are 89.7 m^3/s and 0.65 m^3/s, respectively; major tributaries such as Jellico and Stinking creeks have summer low flows of zero (Ruhl and Martin 1991; USGS 1993). The watershed is mountainous and land use is ca. 84% forest, 13% agriculture, 2.5% mining, and 0.5% urban and developed areas (MSE 1975). Williamsburg, Barbourville, Pineville, Middlesboro, and Harlan, the largest communities in the basin, have a combined population of less than 30,000. Although water quality is improving, many streams continue to be impacted by pollutants associated with coal mining, domestic waste, highway construction, and poor land use (Harker et al. 1980; KDOW 1996).

MATERIALS AND METHODS

We examined 434 upper Cumberland River basin sites for mussels in 1987–1999. All habitats at each site were sampled using a viewing bucket or while snorkeling during low flow when the water was clear. Mussel collections at the Academy of Natural Sciences of Philadelphia (ANSP), Eastern Kentucky University (EKU), Harvard University (MCZ), National Museum of Natural History (NMNH), Ohio State University Museum of Zoology (OSU), and University of Michigan Museum of Zoology (UMMZ) were examined. Species accounts are presented alphabetically following scientific names in Gordon (1995) and Turgeon et al. (1998). Cumberlandian regional endemics and Cumberland River endemics (Gordon 1995; Gordon and Layzer 1989; Ortmann 1924) are indicated. Each annotation includes collection site numbers (Appendix A) followed in parentheses by the number of specimens collected (L = living specimen(s), F = freshly dead, R = relic) during each sampling visit. Results for sites visited more than once are in chronological order. Terms used to summarize distribution follow Smith (1965) and include "generally distributed" (any suitable habitat should yield specimens with a reasonably thorough search), "occasional" (suitable-appearing habitat may or may not yield specimens even after prolonged search), and

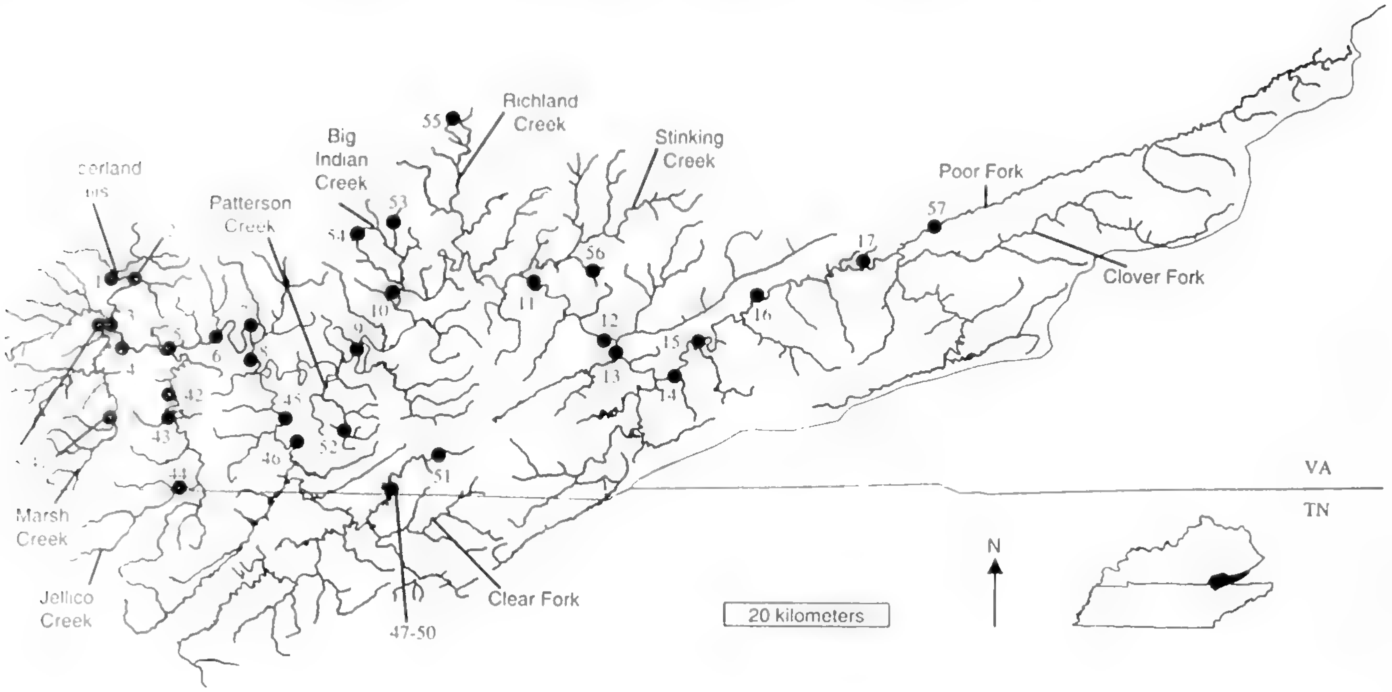

Figure 1. Freshwater mussel collection sites in the upper Cumberland River basin above Cumberland Falls, southeastern Kentucky, 1987–1999. Site numbers are referenced in Appendix A.

"sporadic" (encountering specimens cannot be predicted at all).

SPECIES ACCOUNTS

A brief discussion of the historical and present distribution and status of mussels reported upstream from the falls follows. Only generalized distributional information is presented for *Corbicula fluminea*.

Actinonaias pectorosa (Conrad). Pheasantshell. Cumberlandian regional endemic. Sites: 1(0; 19L, 3R; 16L); 2(8L); 3(14F; 1L); 4(1L); 5(7L); 6(1R); 7(1R); 8(1R); 9(1R); 10(1F); 11(1L, 1R; 1L, 1R); 13(1R; 0); 14(2 2/2R; 0); 16(1R); 18(1F); 19(8L, 1R; 7L, 1F, 1R; 4L, 3F); 20(8L, 1F); 21(3L); 22(1F); 23(1L); 46(1L). This is the most common species in the upper Cumberland River and lower Marsh Creek, where it is occasional to generally distributed; it is sporadic in Clear Fork. It inhabits sand among cobbles or boulders, and sand and coal fines in bedrock fractures. It was not collected by Wilson and Clark (1914), and Neel and Allen (1964) found only one specimen (near Williamsburg) which "appeared to be a recent immigrant."

Alasmidonta atropurpurea (Rafinesque). Cumberland elktoe. Cumberland River endemic. Sites: 19(5L, 3R; 0; 3L, 2R); 20(5L); 21(2L); 22(2L); 23(2L); 24(1L); 25(7L); 26(2L); 27(2L); 28(4L); 29(4L, 5F); 31(8L, 2F); 32(2L, 1R); 33(1L, 1F); 34(9 1/2R; 5L, 2F); 35(1L, 17F; 22L; several L; 5L; 42L); 36(0; 1L); 37(2L; 0); 38(1F); 39(1F); 40(1F); 47(0; 1L); 48(1L; 0; 0); 49(1L); 50(1L). Until recently, this mussel was synonymized under *A. marginata* (Call and Parmalee 1981; Clarke 1981). It historically inhabited the Cumberland River and its southern tributaries in Kentucky and Tennessee, including the Big South Fork of the Cumberland River, upstream from the hypothesized original location of Cumberland Falls near Burnside, Pulaski County, Kentucky (Gordon 1991; Gordon and Layzer 1993). It was not reported by Wilson and Clark (1914) or Neel and Allen (1964), but, as observed by Gordon (1991), historic records for *A. marginata* from the Cumberland River just above the falls, McCreary/Whitley counties (UMMZ 63954), and at Williamsburg, Whitley County (Clarke 1981, MCZ 224076), are *A. atropurpurea*. Downstream from the present falls location, it occurred in the Laurel River, Laurel County, (as *Strophitus undulatus*) (Neel and Allen 1964; UMMZ 172886), Lynn Camp Creek, Whitley County (Clarke 1981), and in the Big South Fork of the Cumberland River above Burnside, Pulaski County (as *A. marginata*) (Wilson and Clark 1914). Wilson and Clark's (1914) record for *A. mar-*

ginata from the Cumberland River near Burnside could be this species. This endangered mussel (KSNPC 1996; USFWS 1998) is sporadic in Laurel Fork of Clear Fork, and it is generally distributed and common in Marsh Creek, where it was discovered by Harker et al. (1980) and Call and Parmalee (1981). It also inhabits the Big South Fork of the Cumberland River, Kentucky and Tennessee, the Rockcastle River, where it occurs sympatrically with *A. marginata* (*contra* Gordon 1991; Gordon and Layzer 1993), and Rock Creek, Kentucky (Cicerello et al. 1991; Gordon 1991, EKU). It lives in sand and silt often among cobbles and boulders in relatively shallow pools and runs (Gordon and Layzer 1989).

Alasmidonta viridis (Rafinesque). Slippershell mussel. Sites: 19(0; 0; 1R); 22(1F); 23(1F); 27(1L); 28(4L); 33(1L); 47(1L; 1L); 48(0; 1R; 1R). Wilson and Clark (1914) collected specimens from the Cumberland River between the falls and Pineville and from the Clear Fork. Neel and Allen (1964) did not find this species and hypothesized that it was lost to acid coal mine drainage. This species is occasional in Marsh Creek, where it was discovered by Harker et al. (1980) and Call and Parmalee (1981), and it is sporadic in Laurel Fork, a Clear Fork tributary. In both streams, small numbers of this easily overlooked mussel inhabit sand or mixed sand, gravel, and silt near boulders.

Anodontoides denigratus (Lea). Cumberland papershell. Cumberland River endemic. Sites: 18(1R); 23(1L); 25(1L); 30(3L); 31(2L, 3F); 32(1L, 1F); 33(1L, 1R); 34(1F, 2 3/2R; 1L); 35(35L, 1F, 2R; 21F; 1L, 4 1/2F; 40L; 73L, 3F); 36(9L; 6L); 37(15L, 3F; 1R); 38(1L, 3F); 39(4F); 40(5L, 1F); 41(3L); 51(15L); 52(8L, 1R; 13L; 10L, 3F); 53(2L; 3L); 54(5L, 1F, 2R; 18L, 1F); 55(10L, 1F, 1/2R; 8L); 56(1R; 1L). This species was described by Lea (1852) and has been confused with *A. ferussacianus* and *Strophitus undulatus*. It is distinctive from the allopatric *A. ferussacianus* according to Gordon (1995), who is redescribing it. It is restricted to the upper Cumberland River on the Cumberland Plateau in Kentucky and Tennessee upstream from the original location of the falls (Gordon 1995). Historically, *A. denigratus* was collected from the Cumberland River at Pineville and Orby, Bell County (Ortmann 1918; Wilson and Clark 1914; UMMZ 105530) (as *A. ferussacianus*), and from the Clear Fork (UMMZ 66141) (as *S. undulatus*). Downstream from the present location of the falls, it is known from Lynn Camp Creek, Whitley County (UMMZ 105533) (as *A. ferussacianus*), and from the Laurel River, Laurel County (Neel and Allen 1964; UMMZ 172886) (as *S. undulatus*). Wilson and Clark's (1914) record for *A. ferussacianus* from the Clear Fork, Jellico, Tennessee, probably is this species (Gordon 1995). This species inhabits Marsh, Moore, Pine, and Rose creeks, Mills Fork, Billies Branch, Demps Hollow, and Rockcastle River tributaries in Kentucky (EKU, KSNPC), and Big South Fork of the Cumberland River tributaries in Tennessee (Gordon 1995). The best population of this endangered mussel (KSNPC 1996) is generally distributed in the middle segment of Marsh Creek, where it comprised 57% of 282 live mussels specimens collected in 1994. Its habitat is identical to that of *A. atropurpurea*, slowly flowing or still pools and runs underlain with silt and sand. It is locally abundant in Moore, Pine, and Rose creeks, Mills Fork, Billies Branch, and Demps Hollow, all first- and second-order streams inhabited only by *A. denigratus*.

Elliptio dilatata (Rafinesque). Spike. Sites: 8F(1F); 11(0; 1R); 19(5L, 1R; 1R; 1F); 20(1L, 2F); 21(1L); 24(1R); 26(1L); 42(1R); 43(1R); 44(1R); 45(1 1/2R). Historically, the spike was the most widely distributed and abundant species above the falls. Wilson and Clark (1914) collected specimens at all of their sampling sites and found that it comprised about 90% of the Clear Fork mussel population. In the late 1940s, it was the predominant species in the upper Cumberland (Neel and Allen 1964). Call and Parmalee (1981) considered the spike common in Marsh Creek, where Layzer and Anderson (1992) also noted its presence. The distribution and abundance of *E. dilatata* have declined greatly throughout the basin. It is sporadic in the Cumberland River, Jellico Creek, and Clear Fork, where we found mainly relic specimens, and relatively common only in lower Marsh Creek.

Lampsilis cardium Rafinesque. Plain pocketbook. Sites: 3(1F; 0); 11(1R; 0); 12(1F); 13(3 1/2R; 0); 14(0; 1L, 3 1/2R); 15(1F, 1R); 16(1R); 19(0; 1L, 1F; 1L, 1F); 20(1L); 22(1R); 23(1L); 24(1R); 35(1L; 0; 0; 0; 1L); 45(2L, 3

3/2R); 56(2L). The plain pocketbook is widely distributed but sporadic in the Cumberland River from the falls upstream to Harlan County and in Marsh Creek, where it was collected by Harker et al. (1980) and Call and Parmalee (1981). It is sporadic in the Clear Fork, Whitley County. Marsh Creek supports the best population above the falls, but only seven living or freshly dead specimens were found at 21 sampling sites in 1994. It formerly was very abundant above and below the falls (Neel and Allen 1964), where Wilson and Clark (1914) failed to find specimens. The only records we found from above the falls that pre-date Neel and Allen (1964) are an undated Bryant Walker collection from the Cumberland River at Williamsburg, Whitley County (MCZ 46747), and collections made in 1941 and 1945 by Clark from the Cumberland River at Molus, Harlan County (MCZ 123966), and 5 miles east of Pineville (UMMZ 165273), respectively.

Lampsilis fasciola Rafinesque. Wavyrayed lampmussel. Sites: 1(1/2R; 0; 0); 9(1R); 10 (1R); 11(1L, 2R; 1/2F); 12(2 F); 13 (4R; 1R); 14(1 2/2R; 2L); 16(2/2F); 17(1L); 19(0; 1F, 1R; 2L); 20(1L); 22(1R); 46(1/2R); 48(0; 0; 2F); 57(1F). Although *L. fasciola* was not collected by Wilson and Clark (1914), Neel and Allen (1964) reported that it was very abundant. Call and Parmalee (1981) and Layzer and Anderson (1992) collected specimens from Marsh Creek. *Lampsilis fasciola* is widely distributed but sporadic in the Cumberland River, Poor Fork, Marsh Creek, and Clear Fork, where it inhabits sand and/or sand, pebbles, and gravel often near cobbles or boulders in shallow pools or runs.

Lampsilis ovata (Say). Pocketbook. Sites: none. Wilson and Clark (1914) collected a few dwarfed specimens from the Cumberland River and reported that *L. ovata* was transplanted into the river above the falls, possibly by pearl collectors (Neel and Allen 1964). This apparent effort to develop a commercially valuable stock failed. Now considered endangered in Kentucky (KSNPC 1996), *L. ovata* apparently has not been collected subsequently; it is considered extirpated from above the falls.

Strophitus undulatus (Say). Creeper. Sites: none. Wilson and Clark (1914) reported specimens from the Cumberland River at Pineville, collected by their collaborator J. F. Boepple, and from the Clear Fork, Tennessee. Neel and Allen (1964) listed it from the Cumberland River at Pineville and at Wallins (near Harlan), but stated that "[i]n the present survey only 4 forms occurred above the falls: *L. fasciola, L. ovata ventricosa* (=*L. cardium*), *E. dilatatus*, and *A. pectorosa*." We did not find *S. undulatus* and we were unable to locate specimens from the area for re-examination. Based on the following, we believe Wilson and Clark's (1914) records for *S. undulatus* from above the falls are actually *A. denigratus*. We re-identified two specimens of *S. undulatus* collected by Hubbs from the Clear Fork, Whitley County, (UMMZ 66141) as *A. denigratus*. Wilson and Clark (1914) and Neel and Allen (1964) also reported *S. undulatus* from the Rockcastle and Laurel rivers. Both *S. undulatus* and *A. denigratus* inhabit the Rockcastle River basin (KSNPC, MCZ), but we re-identified Neel and Allen's (1964) *S. undulatus* specimens from the Laurel River at Lily (UMMZ 172886) as *A. denigratus* and *A. atropurpurea*. Wilson and Clark (1914) noted that their *S. undulatus* specimens were "exceedingly variable and presented many puzzling forms," indicating difficulty in making identifications. Finally, the shell descriptions and the picture of *S. undulatus* in Wilson and Clark (1914) and Neel and Allen (1964) also could be interpreted as *A. denigratus*.

Toxolasma parvus (Barnes). Lilliput. Sites: none. Known from only one specimen collected by C. Goodrich from the Cumberland River northwest of Pineville, Bell County (UMMZ 99672). The lilliput can be overlooked because of its small size, but it probably is extirpated.

Villosa lienosa (Conrad). Little spectaclecase. Sites: none. A specimen collected by H.D. Athearn from the Cumberland River near Barbourville, Knox County, (HDA 13857) in 1966 is the only record of this rare Kentucky mussel (KSNPC 1996) from above the falls. This record is interesting because Richland Creek, a nearby tributary, lies in close proximity to Collins Fork, a Kentucky River tributary that supports one of Kentucky's largest *V. lienosa* populations (Cicerello pers. obs.). Geological evidence and fish distribution patterns identify this area as a stream capture theater, with probable multiple faunal exchanges between the drainages during recent geological times (Burr and Warren 1986; Kuehne and Bailey 1961). Stream capture occurs when natural erosion cuts across a headwater drainage divide and a stream segment and its biota are diverted from one basin into another. *Villosa lienosa* is absent, extirpated, or rare in the adjacent Tennessee, Cumberland (below the falls), and Big Sandy rivers (Beetle 1973; Cicerello et al. 1991; Starnes and Bogan 1988), and it is tempting to invoke stream capture and transfer of its fish host from the Kentucky River drainage as the source of this highly localized record. However, even the most suggestive stream capture evidence may lead to invalid conclusions, and limited distributions may result from introductions rather than natural factors (Jenkins et al. 1971). The origin of *V. lienosa* is unclear; the species probably is extirpated.

INTRODUCED SPECIES

Corbicula fluminea (Müller). Asian clam. This introduced, exotic clam is the most common and widely distributed mussel above the falls. It inhabits the mainstem from the falls to near the headwaters of the Poor Fork, the lower half of Marsh Creek, Jellico Creek nearly to the Tennessee border, Clear Fork upstream into Mud Creek and Laurel Fork, Big Indian Creek including Mills Fork, lower Stinking Creek, and Martins Fork upstream to Martins Fork Lake. Densities exceed 100/m^2 in Marsh Creek.

DISCUSSION

We found a total of seven species, all living or freshly dead, at 57 of the 434 sites sampled (Table 1). With the exception of Marsh Creek and other streams inhabited by *A. denigratus*, mussels generally are sporadic and restricted to the mainstem Cumberland River and to the Clear and Poor forks. Species richness is greatest in Marsh Creek (7 species), Clear Fork (6), and the mainstem Cumberland River (4), and several streams support only one species (e.g., Big Indian, Jellico, Patterson creeks, and the Poor Fork). *Lampsilis fasciola* is the most widely distributed native species, inhabiting the Cumberland River from the falls upstream ca. 216 river km into Poor Fork, Marsh Creek, and Clear Fork.

Three species found mainly in tributaries comprised ca. 92% (613/667) of the living or freshly dead specimens encountered. *Anodontoides denigratus*, the most abundant species, is restricted to Marsh Creek, Clear Fork, and segments of Big Indian, Patterson, Richland, and Stinking creeks. *Alasmidonta atropurpurea* is found primarily in Marsh Creek, as is *A. pectorosa*, which lives also in the Cumberland River from the falls to above Yellow Creek. *Elliptio dilatata* and, to a lesser extent, *L. cardium* and *L. fasciola*, formerly were the dominant species in the mainstem Cumberland River (Neel and Allen 1964; Wilson and Clark 1914). Their decline in abundance is a result of persistent and varied water quality problems (Charles 1966; Jillson 1927; KDOW 1996, 1998).

Eleven species have been reported above the falls, but only as many as nine are native to the area. Specimens previously reported as *S. undulatus* probably were mis-identified *A. atropurpurea* and *A. denigratus*. *Lampsilis ovata* was introduced into the basin (Wilson and Clark 1914). *Toxolasma parvus* and *V. lienosa* each were collected only once from the basin and are considered extirpated from there.

Marsh Creek is the most important refuge for mussels in the upper Cumberland River basin. It is the most species-rich, and it supports the best populations of all mussels except *A. pectorosa*. More than 70% (471/667) of all living and freshly dead specimens we encountered were found in Marsh Creek. The presence of *Phoxinus cumberlandensis* (USFWS (1998) threatened species) and *Etheostoma nigrum susanae* (KSNPC (1996) threatened species), upper Cumberland River basin endemic fishes, increase the importance of Marsh Creek as an epicenter for recolonization of degraded streams throughout the basin.

We note several challenges to the protection of the biological diversity and integrity of Marsh Creek that also threaten other basin streams. Marsh Creek has relatively good water quality, but it is being impacted by silt from farms and inactive coal strip mines (KDOW 1996). A National Resources Conservation Service (formerly the Soil Conservation Service) proposal to remove the silt by channelizing upper Marsh Creek was rebuffed, but this proposal could resurface despite recommendations to identify and revegetate eroding areas. Previously mined areas also could be remined to obtain formerly inaccessible or unprofitable coal deposits. The development of oil resources in uplands along the stream poses a renewed threat to the biota. A 1987 oil spill killed hundreds of A. *atropurpurea* and A. *denigratus* along an undetermined length of Marsh Creek (Cicerello pers. obs.). Finally, a 1965 United States Army Corps of Engineers proposal to construct a 24+ m high dam on the Cumberland River 1.6 km upstream from Cumberland Falls was revived in 1995 by local entities interested in hydroelectric generation and recreation. This project would embay the Cumberland River upstream into lower Marsh Creek and adversely impact the aquatic biota and water quality.

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APPENDIX A

Upper Cumberland River basin mussel collection sites in southeastern Kentucky listed by and within sub-basins from down- to upstream. Site numbers refer to numbers in Figure 1.

CUMBERLAND RIVER MAINSTEM: (1.) Just above Cumberland Falls. McCreary/Whitley cos. 28 Apr, 10 Sep 1987; 14 Sep 1995. (2.) Between Cumberland Falls and Ryans Branch. McCreary/Whitley cos. 30 Jul 1993. (3.) At Marsh Creek. McCreary/Whitley Cos. 3 Jul, 10 Aug 1993. (4.) Between Buck Shoals and Crow creeks. McCreary/Whitley cos. 10 Aug 1993. (5.) At Summer Shoals. Whitley Co. 29 Jul 1993. (6.) At Rough Shoals Creek. Whitley Co. 27 Jul 1994. (7.) At Interstate 75. Whitley Co. 27 Jul 1994. (8.) KY 296 at Williamsburg. Whitley Co. 27 Jul 1994. (9.) At Whetstone Creek. Whitley Co. 28 Jul 1994. (10.) Ca. 1 km downstream from Big Indian Creek. Knox Co. 30 Sep 1994. (11.) Ca. 1.9 km upstream from Stinking Creek. Knox Co. 14 Jul, 22 Sep 1993. (12.) At Pineville. Bell Co. 5 Aug 1993. (13.) Ca. 1.6 km downstream from KY 119. Bell Co. 2 Aug 1990; 29 Sep 1994. (14.) KY 1344 at Calvin. Bell Co. 10, 23 Sep 1993. (15.) At KY 987. Bell Co. 23 Sep 1993. (16.) At Minton Branch. Bell Co. 29 Jul 1994. (17.) At Fourmile Branch. Harlan Co. 8 Jun 1994. MARSH CREEK: (18.) Ca. 0.8 km upstream from mouth. McCreary Co. 10 Aug 1994. (19.) Ca. 0.2 km downstream from Brushy Creek. McCreary Co. 16 Aug 1989; 9, 18 Aug 1994. (20.) At Hens Nest Creek. McCreary Co. 10 Aug 1994. (21.) Ca. 2.7 km upstream from Hens Nest Creek. McCreary Co. 11 Aug 1994. (22.) Ca. 3.3 km upstream from Hens Nest Creek. McCreary Co. 11 Aug 1994. (23.) At trib. 3.6 km upstream from Hens Nest Creek. McCreary Co. 10 Aug 1994. (24.) At tributary ca. 1 km downstream from KY 679. McCreary Co. 3 Aug 1994. (25.) At KY 679. McCreary Co. 15 Aug 1989. (26.) At tributary ca. 0.5 km downstream from KY 679. McCreary Co. 3 Aug 1994. (27.) Ca. 0.4 km upstream from KY 679. McCreary Co. 3 Aug 1994. (28.) Ca. 0.5 km downstream from Laurel Creek. McCreary Co. 8 Aug 1994. (29.) Ca.

1 km downstream from Duck Run. McCreary Co. 9 Aug 1994. (30.) Ca. 0.2 km downstream from Taylor Branch. McCreary Co. 3 Aug 1994. (31.) At KY 478. McCreary Co. 30 Aug 1987. (32.) Ca. 0.3 km upstream from KY 478. McCreary Co. 11 Aug 1994. (33.) At Big Branch. McCreary Co. 12 Aug 1994. (34.) Downstream from Kidd School Road Ford. McCreary Co. 15 Aug 1989; 4 Aug 1994. (35.) Ca. 0.3 km upstream from Kidd School Road Ford. McCreary Co. 30 Aug 1987; 28 Apr 1993; 12 Jul 1994; 4, 17 Aug 1994. (36.) Ca. 0.5 km upstream from Kidd School Road Ford. McCreary Co. 4, 17 Aug 1994. (37.) Ca. 0.7 km downstream from KY 1044. McCreary Co. 2, 12 Aug 1994. (38.) Ca. 0.2 km downstream from KY 1044. McCreary Co. 2 Aug 1994. (39.) At KY 1044. McCreary Co. 18 Jul 1989. (40.) Ca. 0.1 km upstream from KY 1044. McCreary Co. 2 Aug 1994. (41.) Ca. 0.2 km downstream from Clear Creek. McCreary Co. 2 Aug 1994. JELLICO CREEK: (42.) Ca. 4.4 km downstream from KY 92. Whitley Co. 6 Jul 1994. (43.) Ca. 2.0 km downstream from KY 92. Whitley Co. 6 Jul 1994. (44.) Downstream from Shut-in Branch. McCreary Co. 12 May 1993. CLEAR FORK: (45.) At Tackett Creek. Whitley Co. 7 Jul 1994. (46.) At Buck Creek. Whitley Co. 7 Jul 1994. (47.) Laurel Fork at TN border. Whitley Co. 27 Jul 1993; 21 Sep 1996. (48.) Laurel Fork ca. 0.4 km upstream from TN border. Whitley Co. 27 Jul 1993; 11 Jan 1994; 26 Sep 1996. (49.) Laurel Fork ca. 0.7 km upstream from TN border. Whitley Co. 27 Jul 1993. (50.) Laurel Fork ca. 0.9 km upstream from TN border. Whitley Co. 27 Jul 1993. (51.) Pine Creek at KY 190. Bell Co. 28 May 1999. PATTERSON CREEK: (52.) Rose Creek ca. 0.2 km upstream from Patterson Creek. Whitley Co. 16 Jun, 15 Oct 1993; 22 May 1997. BIG INDIAN CREEK: (53.) Demps Hollow ca. 1.3 km upstream from Big Indian Creek. Knox Co. 21 Jul 1993, 20 May 1997. (54.) Mills Fork ca. 0.8 km upstream from Big Indian Creek. Knox Co. 21 Jul 1993, 21 May 1997. RICHLAND CREEK: (55.) Billies Branch ca. 3.2 km upstream from Richland Creek. Knox Co. 22 Jul 1993, 20 May 1997. STINKING CREEK: (56.) Moore Creek ca. 10.5 km NW Pineville. Knox Co. 28 Jan 1993, 21 May 1997. POOR FORK: (57.) 0.6 km upstream from Middleton Branch. Harlan Co. 24 May 1994.

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Morphometric Variation of Cotton Mice (*Peromyscus gossypinus*) an White-footed Mice (*P. leucopus*) in Kentucky

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ABSTRACT

We captured 151 white-footed mice (*Peromyscus leucopus*) and 38 cotton mice (*P. gossypinus*) in Ballard and Carlisle counties, Kentucky, during 3600 trap nights. There were significant differences between the two species in body mass, hind foot length, condylobasal length, and length of the nasal bone for both adult males and females. Morphological characteristics often used to differentiate the two species were not always sufficient to do so accurately. Large white-footed mice may be misidentified as cotton mice.

INTRODUCTION

Cotton mice occur in southeastern United States from eastern Texas and Oklahoma east to Florida and north to Virginia (Jones and Birney 1988). With regard to body size, the largest of the three commonly recognized subspecies, *Peromyscus gossypinus megacephalus* (Rhoads 1894), is found at the northern periphery of the range. Cotton mice are uncommon in Kentucky, Missouri (Hall 1981), and the southernmost five counties of Illinois (Feldhamer et al. 1998; Hoffmeister 1989). The preferred habitat of cotton mice, "coincident with the location of rivers, streams, and other lowland areas" (McCarley 1963:787), includes swampy woodlands, bottomlands, lowland forests, and sites near swamps, sloughs, oxbow lakes, and areas with high water tables (Goodpaster and Hoffmeister 1952; Laerm and Boone 1994; Linzey et al. 1976; H. McCarley 1954a, 1954b, 1963; W.H. McCarley 1964; Pournelle 1952). Woody debris is used extensively (McCay 2000).

Cotton mice are sympatric throughout much of their range with white-footed mice (*P. leucopus*). The two species presumably diverged recently (Hooper 1968) and can be difficult to distinguish in the field. The purpose of our study was to compare morphometric characteristics of cotton mice from western Kentucky, where the species is considered to be threatened, with sympatric white-footed mice.

METHODS

Live trapping occurred from August 1998 through April 1999. Twelve sites were selected in Ballard and Carlisle counties, Kentucky (Bekiares 2000). Two Sherman live traps were set at each station, with stations established 10 m apart along a 500-m transect. Traps were set at two sites each week and checked between 0600 and 1000. Traps were set close to fallen logs, brush piles, stumps, pond edges, tree trunks, and on floating debris whenever possible to optimize trap success for *P. gossypinus*. Traps were baited with cracked corn and sunflower seeds and were set for three consecutive nights at each site, for a total of 300 trap nights per site. During summer, traps exposed to sunlight were covered with leaves to decrease the amount of heat absorbed by the trap prior to checking. During cold temperatures, traps contained polyester fiberfill bedding material.

The sex, age class (juvenile or adult, determined by pelage color), and wet body mass (nearest g) of captured animals were recorded. Individuals were then checked for a previous capture mark. If the animal was new, a hind foot measurement (mm) was taken. New captures were marked with a green permanent marker along the ventral surface (Schmid 1998). Marks could be observed for the duration of the three trap nights at each site.

Because *P. leucopus* and *P. gossypinus* are morphologically similar and difficult to distinguish in the field, initial size criteria of Hoffmeister (1977, 1989) were used to separate the species. Individuals with hind foot length ≥22 mm or body mass ≥26 g were tentatively identified as *P. gossypinus*. These animals

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were euthanized using cervical dislocation, placed on ice, and returned to the laboratory. Allozyme analyses (Bekiares 2000) were used to confirm species identification of animals collected. Other rodents, birds, and reptiles of non-interest were released at the capture site.

For animals removed from the field, standard external measurements (in mm) were made prior to dissection: total body length, tail length, ear length, and hind foot length. In addition, wet body mass (g) was recorded a second time using a triple-beam balance. Measurements (mm) of cleaned skulls included condylobasal length, length of the nasal bone, and length of the maxillary toothrow.

The computer program Statview was used to compute unpaired t-tests for comparisons of means, Z-tests for comparisons of proportions, and general descriptive statistics. Statistical tests were considered significant at $\alpha = 0.01$.

RESULTS

During 3600 trap nights we captured 197 individuals: 151 white-footed mice, 38 cotton mice, three rice rats (*Oryzomys palustris*), one Eastern chipmunk (*Tamias striatus*), and four leopard frogs (*Rana sphenocephala*). Seven of the *P. leucopus* were believed to be *P. gossypinus* upon capture and were removed from the field.

Only data from adults were used in morphological analyses because of the differences in juvenile sizes. Another consideration is that females collected in late summer and autumn may be pregnant. We collected only six pregnant females and chose to remove them from analyses. As expected, adult *P. leucopus* were significantly smaller than *P. gossypinus* for four of the eight measurements examined. For males, *P. leucopus* were significantly smaller than *P. gossypinus* in body mass, hind foot length, condylobasal length, and nasal length (Table 1). Female *P. leucopus* were smaller than female *P. gossypinus* for the same four measurements.

DISCUSSION

Most of the mean values for morphological characteristics of white-footed mice in our study represent a biased sample. Only those *P. leucopus* tentatively identified as *P. gossypinus* in the field were used for all measurements and represented the largest individuals. Only the hind foot and body mass measurements represent an unbiased sample because data were obtained on all animals captured in the field, not just those presumed to be *P. gossypinus*. We expect that the other four characteristics measured (total length, tail length, ear length, and maxillary toothrow length) also would be significantly smaller in an unbiased sample of *P. leucopus*.

Cotton mice in this study were significantly larger than six specimens reported from Horseshoe Lake Conservation Area, Alexander County, Illinois (Feldhamer et al. 1998). It is possible that the Illinois specimens were large *P. leucopus* misidentified as *P. gossypinus*. More likely, we suspect they may have been hybrids between the two species. Barbour and Davis (1974) suggested hybrid cotton mice occurred in Kentucky. Other investigators have also noted hybridization between the two species (Lovecky et al. 1979; McCarley 1954b; St. Romain 1976; although see Bradshaw 1968), with hybrids exhibiting intermediate-sized morhological characters.

Boone (1995) analyzed morphometric data for cotton mice from throughout their range. Using only adults, we compared his data to our data from Kentucky. For all morphological traits considered in both studies, Kentucky specimens, from the periphery of the range, were significantly larger ($P < 0.01$; see Bekiares 2000). This is consistent with the clinal size relationship noted by Boone (1995) for cotton mice throughout their range.

Hoffmeister (1977, 1989) created a scattergram based on morphological characters to distinguish between cotton mice and white-footed mice. He used hind foot length × nasal bone length on the x-axis, and condylobasal length × maxillary toothrow length on the y-axis. Measurements of cotton mice group to the right of a line running approximately through (0, 134) and (275, 0). In our study, specimens "on the line" were white-footed mice, based on allozyme data (Bekiares 2000).

Use of morphological measurements may need to be more conservative for differentiating white-footed mice and cotton mice on the periphery of their range in Kentucky, Illinois, and Missouri. That is, "questionable" specimens on or near the right side of the de-

Table 1. Differences (t-test; * = $P \leq 0.01$) in mean values of morphological characteristics between specimens o adult *Peromyscus gossypinus* and *P. leucopus* from Ballard and Carlisle counties, Kentucky, — collected between August 1998 and April 1999. Variation is reported as standard error.

Characteristic	*P. gossypinus*	*P. leucopus*	T_{cal} value
Male body mass (g)	30.97 ± 1.20 n = 17	22.95 ± 0.45 n = 57	7.65*
Female body mass (g)	33.18 ± 1.04 n = 21	24.69 ± 1.01 n = 33	−5.62*
Male total length	170.82 ± 3.61 n = 17	159.00 ± 5.21 n = 4	1.49
Female total length	179.57 ± 1.12 n = 21	174.00 ± 7.77 n = 3	1.42
Male tail length	74.47 ± 2.53 n = 17	66.25 ± 206 n = 4	1.52
Female tail length	77.90 ± 1.03 n = 21	82.67 ± 5.04 n = 3	−1.48
Male hind foot length	22.71 ± 0.27 n = 17	17.62 ± 0.27 n = 68	8.98*
Female hind foot length	22.81 ± 0.20 n = 21	18.01 ± 0.33 n = 35	−9.34*
Male ear length	18.76 ± 0.31 n = 17	18.00 ± 0.41 n = 4	1.14
Female ear length	18.86 ± 0.51 n = 21	17.00 ± 3.06 n = 3	1.09
Male condylobasal length	28.05 ± 0.27 n = 17	25.56 ± 0.59 n = 4	4.00*
Female condylobasal length	28.39 ± 0.14 n = 21	27.03 ± 0.55 n = 3	3.34*
Male nasal length	11.41 ± 0.21 n = 17	9.61 ± 0.28 n = 4	3.99*
Female nasal length	11.22 ± 0.16 n = 21	10.03 ± 0.21 n = 3	2.75
Male maxillary toothrow	3.94 ± 0.08 n = 17	3.77 ± 0.19 n = 4	0.93
Female maxillary toothrow	3.98 ± 0.06 n = 21	3.73 ± 0.02 n = 3	1.62

marcation line of Hoffmeister (1977, 1989) should be considered *P. leucopus*.

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Woody Plants of Six Northern Kentucky Counties

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ABSTRACT

Our field work and herbarium surveys have documented the woody flora of Bracken, Fleming, Harrison, Mason, Nicholas, and Robertson counties, Kentucky. The presently known woody flora consists of 172 taxa; 11% of the woody flora is exotic. We report *Thuja orientalis* L. for the first time as an introduced member of Kentucky's flora. There is a significant discontinuity of distribution between the northern Bluegrass and Knobs regions. *Arundinaria gigantea* is a much rarer plant in northern Kentucky than conventional wisdom indicates. We include an annotated listing of woody plant taxa and a discussion of the state of natural habitats and potential impact of weedy woody species.

INTRODUCTION

Narratives related to the natural features of Kentucky have typically attested to an abundance and variety of natural resources. A recent, statewide assessment of biodiversity in Kentucky (Taylor 1995) convincingly argues that plant diversity in the state is substantial. However, in spite of recent attempts to estimate vascular plant diversity in Kentucky (Browne and Athey 1992; Medley 1993), sufficient information is not yet available for an accurate estimate of which vascular plant taxa actually occur in the state. Contributing reasons for this situation include repeated anecdotal and unvouchered reports of occurrences and a general paucity of vouchered collections in institutional herbaria (Jones et al. 1995).

However, the situation we find ourselves in is beside the point. The point is, too little is known about the flora of Kentucky, land use trends are continually shrinking and modifying native habitats, and we are at risk of losing elements of the flora before we discover the full extent of its diversity and distribution. There is an urgent need for more thorough documentation of the flora of Kentucky.

SCOPE AND JUSTIFICATION OF THIS STUDY

Our study was undertaken to document the occurrence of woody plants that are native, naturalized, or spreading from cultivation in six counties of northern Kentucky: Bracken, Fleming, Harrison, Mason, Nicholas, and Robertson. Our goal was to document the woody plant diversity in these counties at greater than the 90% level.

One of the reasons this region was selected for study is because it is not well known botanically. Guetig (1993) compiled a summary of all floristic work previously done in Kentucky. His summary indicated that none of the counties included in the present study has ever been the subject of an organized effort to document the flora. Also, we felt that thorough vouchering of the woody plants of these counties would make subsequent field work to voucher the herbaceous vascular plants easier. (The logistics of field collecting are simpler when one is not continually searching for all sizes of plants.) In addition, woody plants were selected as the focus of our study because they are keystone organisms in forest and savanna ecosystems and have considerable economic significance. We felt that documenting the occurrence of this portion of the flora would be a connection to Kentucky's heritage that people would be more likely to appreciate. Finally, most of this area of the state is typified by an advanced state of habitat elimination and modification. Consequently, we concluded that, if efforts to document the flora were delayed much longer, significant elements of the woody flora could possibly be lost entirely.

THE STUDY AREA

All of the counties lie within the drainage of the Licking River, except for the northern portions of Mason and Bracken counties, which are drained by creeks downcutting directly to the Ohio River. The six county study area totals almost 1700 mi^2 (438,000 ha), which is almost 4.3% of the land area of Kentucky (Anonymous 2000a).

Elevations within the study area range from about 500 ft. (152 m) above mean sea level near Meldahl Dam on the Ohio River in northwestern Bracken County, to about 1200 ft. (370 m) above sea level in extreme eastern Fleming County. The maximal elevation attained in the Bluegrass part of our study area is about 1000 ft. (305 m), in extreme southwestern Harrison, near Leesburg (U.S. Geological Survey 1976, 1978).

All of the study area except eastern Fleming County lies within the Bluegrass Region of Kentucky. The Bluegrass is underlain by Ordovician strata. Main geologic formations include Lexington Limestone where exposed by downcutting of main tributaries of the western and northern Licking River, with Garrard Siltstone and the Clays Ferry Formation comprising most of the rolling uplands of the western part of the study area. Proceeding eastward from the former exposures, one encounters relatively narrow outcropping belts of the (Ordovician) Bull Fork Formation, Drakes Formation, and Crab Orchard Formation (both of these Silurian and marking the transition between Knobs and Bluegrass), and finally, Devonian and Mississippian strata of the extreme western edge of the Mississippian Plateau. (McDowell et al. 1981) Only extreme eastern Fleming County is within the physiographic province known as The Knobs, characterized (sequentially as one goes eastward) by outcropping Silurian, Devonian, and Mississippian rocks. The Knobs are interpreted as the dissected remnant of the Mississippian (Interior Low Plateau) Province, known parochially in Kentucky as the Pennyrile Plateau (Fenneman 1938; Karan and Mather 1977). Except over heavily organic Ohio shale in the Knobs, most upland soils of our study region have an alkaline pH.

Estimates of the original vegetation in this region vary and are still debated, possibly because originally there was a complex mosaic from which fire has now been systematically excluded for 200 years. It may have included a preponderance of ash-oak-prairie savanna in the Inner Bluegrass and various facies of oak-chestnut and mixed mesophytic on the Knobs (Braun 1950; Bryant 1987; Campbell 1980; Küchler 1964; Martin et al. 1978).

MATERIALS AND METHODS

Prior to field collecting, each county was surveyed to determine areas which might yield more habitat diversity. Because of the relative lack of geologic diversity in most of the study area, this survey relied on physiographic maps and county road maps (Anonymous 1997; Puetz n.d.; U.S. Geological Survey 1976, 1978). By this method, we were able to identify circumstances with a high likelihood of giving us efficient and repeated coverage of major habitats within each county.

About two field collecting days were spent in each county. Field work began on 7 Jun 1999 and ended 20 Jul 1999. Specimens were collected wherever we found them first, from roadsides and ruderal habitats to reasonably intact habitats. Specimens were temporarily held in wet newspaper within large polyethylene bags and later accessioned by collector, pressed, dried, labeled, and determined to taxon. The senior author determined the taxa of most specimens without consulting additional sources, except to verify nomenclatural authorship. The field work required 2441 miles of travel, an average of about 3 miles (4.8 km) for each taxon collected.

Nomenclature in this report is generally according to Gleason and Cronquist (1991), which also was a source consulted for determination of some groups. The International Plant Name Index (Anonymous 2000b) and Rehder (1940) were consulted in a few cases, and we used Fernald (1950) as an aid to the determination specimens of specimens of *Crataegus* and *Rubus*.

Following processing and determination of our field collections, herbarium collections at EKY, UKY, MDKY, and KNK were surveyed to see if additional taxa had been vouchered in these counties by other collectors. These surveys yielded a few (<1%) additional records. Travel to herbaria required 3 additional work days and about 500 miles (800 km) of

Table 1. Comparative woody plant diversity data for six northern Kentucky counties.

	Bracken	Fleming	Harrison	Mason	Nicholas	Robertson	Totals
Area^{1,2}	495^1	351^1	309^1	241^1	196^1	100^1	1692^1
Total number of taxa	109	140	110	100	96	97	172
Number of native taxa	92	124	95	82	78	83	142
Number of non-native taxa	15	16	15	18	18	14	19
% Non-native	12.1	11.4	13.6	18.0	18.9	14.4	11
Human density/mi^2 ^{1}	38.9	350	52.6	40	34.3	22.2	

[1] in sq. mi.

[2] Source: Anonymous 2000.

additional travel. See Table 1 for statistical floristic data.

RESULTS

The field effort resulted in more than 760 collections from the study area. Our subsequent regional herbarium survey yielded a few additional records. Overall, this study resulted in the documentation of 172 woody taxa from the six-county area. Fleming County, with 140 documented taxa, has the most diverse woody flora. Robertson County, with 97 documented taxa, has the least diverse woody flora (Table 1). Information from the Internet is cited here in accordance with the standard proposed by Walker (1995).

ANNOTATED VOUCHERS OF THE WOODY FLORA

Below is a list of vouchers for the woody plants of the six-county study area, followed by citations of voucher specimens and a short comment on the pattern of occurrence. To save space, names of counties of origin of voucher specimens (Bracken, Fleming, Harrison, Mason, Nicholas, Robertson) are abbreviated to first letter in parentheses after voucher numbers. When only a number is listed, it is the accession number of the senior author and the specimen has been deposited in EKY. Vouchers from other Kentucky workers are more completely cited. Nomenclature generally follows Gleason and Cronquist (1991), but in the final analysis reflects the judgment of the senior author. Abbreviations for herbaria are from Holmgren and Holmgren (2000).

Little (1971, 1977) included some additional distributional data for a few taxa within our study area. Presumably, the vouchers on which some of his data are based are in herbaria not consulted during this study. Therefore, his vouchers are not referenced here. We conservatively estimate that the specimens collected during our study constitute more than 95% of the data now extant for woody plants in this six-county area of Kentucky.

PINOPHYTA

Cupressaceae

Juniperus virginiana L.—24915 (B), 25273 (F), 24657 (H), 24782 (M), 25154 (N), 25038 (R). Common throughout. This is apparently the only gymnosperm native in the Bluegrass.

Thuja orientalis L.—25057 (R). Mature offspring from nearby cultivated plants are established in a fencerow. Introduced; This is apparently the first report of plants of this taxon escaping in Kentucky (Brown and Athey 1992; Medley 1993).

Pinaceae

Pinus echinata Miller—25244 (F). Occasional, Knobs.

Pinus rigida Miller—25227 (F). Frequent, Knobs.

Pinus virginiana Miller—25275 (F). Common, Knobs.

ANTHOPHYTA

Aceraceae

Acer negundo L.—24869 (B), 25282 (F), 24628 (H), 24788 (M), 25147 (N), 25011 (R). Common throughout.

Acer nigrum Michaux f.—24957 (B), 25322 (F), 24611 (H), 24799 (M), 25091 (N), 25024 (R). Mesic woods, usually on north- and east-facing slopes or in alluvium along streams.

Acer rubrum L.—25310 (F). Frequent in various habitats, Knobs.

Acer saccharinum L.—24956 (B), 25342 (F), 24606 (H), 24770 (M), 25136 (N), 24964 (R). Frequent; low ground along streams and terraces.

Acer saccharum Marshall—24901 (B), 25232 (F), 24651 (H), 24796 (M), 25128 (N), 25020 (R). Frequent; various upland habitats.

Anacardiaceae

Rhus aromatica L.—25327 (F), 24613 (H). Xeric blufftops; rare.

Rhus copallina L.—25277 (F), 24648 (H), 25077 (R). Disturbed rights-of-way; rare.

Rhus glabra L.—24912 (B), 25271 (F), 24644 (H), 24831 (M), 25123 (N), 25029 (R). Various habitats, most common in fencerows.

Rhus typhina L.—24832 (B), 24774 (M). Mesic woods and low ground; infrequent; confined to habitats near the Ohio River.

Toxicodendron radicans (L.) Kuntze—24946 (B), 25281(F), 24597 (H), 24756 (M), 25151 (N), 25079 (R).Various habitats; common.

Toxicodendron pubescens Miller—24874 (B), 24707 (H). Xeric woods; rare.

Annonaceae

Asimina triloba (L.) Dunal—24889 (B), 25313 (F), 24646 (H), 24758 (M), 25139 (N), 24990 (R). Various mesic and alluvial habitats; frequent.

Apocynaceae

Vinca minor L.—25218 (F), 25047 (H), 24802 (M), 25047 (R). Introduced; ruderal habitats and dump sites; infrequent.

Araliaceae

Aralia spinosa L.—25286 (F). Mesic and alluvial habitats; Knobs.

Hedera helix L.—24850 (B). Introduced; dump site; rare.

Berberidaceae

Berberis thunbergii DC.—24867 (B), 25048 (H), 25094 (N), 25048 (R). Introduced. Various disturbed and degraded habitats; infrequent.

Betulaceae

Alnus serrulata (Aiton) Willd.—Thieret s.n., 30 Jan 1983 (KNK) (B), 25235 (F), 24807 (M). Streambanks and low, open ground; infrequent; apparently absent from Bluegrass.

Betula nigra L.—25338 (F). Alluvial woods, rare; Knobs.

Carpinus caroliniana Walter—24924 (B), 25307 (F), 24701 (H), 24754 (M), 25095 (N), 24991 (R). Various habitats, usually mesic; frequent to occasional.

Corylus americana Walter—24879 (B), 25289 (F), 24694 (H), 25025 (R). Bluffs and mesic habitats; infrequent.

Ostrya virginiana (Miller) K. Koch—24909 (B), 25203 (F), 24617 (H), 24746 (M), 25096 (N); common.

Bignoniaceae

Bignonia capreolata L.—25324 (F), 24619 (H), 25025 (R). South- and west-facing bluffs along major streams; rare, but locally common.

Campsis radicans (L.) Seemann—24897 (B), 25241 (F), 24653 (H), 24798 (M), 25146 (N), 25015 (R). Most habitats; common.

Catalpa bignonioides Walter—24837 (M), 25132 (N). Low woods, rare. In spite of its common name (southern catalpa), this species appears to be native along the Ohio River in the study area. However, both this species and the following one are cultivated and can be expected to produce adventive plants.

Catalpa speciosa Warder—24586 (H). An apparent escape from cultivation; Cynthiana.

Caesalpiniaceae

Cercis canadensis L.—24903 (B), 25255 (F), 24681 (H), 24767 (M), 25170 (N), 25039 (R). Various habitats; common throughout.

Gleditsia triacanthos L.—24917 (B), 25207 (F), 24661 (H), 24755 (M), 25145 (N), 25002 (R). Various habitats; common throughout.

Gymnocladus dioica (L.) K. Koch—24836 (B), 24332 (F), 24624 (H), 24721 (M), 25160 (N), 25073 (R). Disturbed habitats and mesic woods; infrequent.

Caprifoliaceae

Lonicera japonica Thunberg—24098 (B), 25314 (F), 25052 (H), 25353 (M), 25155 (N), 25054 (R). Introduced; most habitats; common.

Lonicera maackii (Rupr.) Herder—24940 (B), 25251 (F), 24632 (H), 24772 (M), 25166 (N), 24976 (R). Introduced; most habitats; common in counties bordering the Ohio River. In our opinion, this is one of the potentially most ecologically disastrous terrestrial plants ever introduced into eastern North America. It eliminates or severely inhibits the reproduction of most native Eastern Deciduous Forest plants.

Sambucus canadensis L.—24833 (B), 25252 (F), 24695 (H), 24778 (M), 25174 (N), 24969 (R). Stream corridors, low ground, and mesic woods; common.

Symphoricarpos orbiculatus Moench—24885 (B), 25215 (F), 24664 (H), 24810 (M), 25116 (N), 25033 (R). Various habitats; frequent.

Viburnum acerifolium L.—25309 (F). Deciduous woods; Knobs.

Viburnum prunifolium L.—24937 (B), 25221 (F), 25051 (H), 24747 (M), 25120 (N), 25058 (R). Upland woods, blufftops, fencerows, and disturbed habitats; frequent.

Viburnum rufidulum Raf.—24894 (B), 25336 (F), 24682 (H), 24764 (M), 25124 (N), 25036 (R). Upland woods and disturbed habitats; frequent.

Celastraceae

Celastrus scandens L.—24914 (B), 25315 (F), 24671 (H), 24829 (M), 25140 (N), 25037 (R). Upland and mesic woods and disturbed habitats; common.

Celastrus orbiculatus Thunberg—25339 (F), 25104 (N). Introduced; ruderal habitats and rights-of-way. Presently uncommon in the study area and often confused with plants of the preceding taxon. In our area, this species may have the potential of eclipsing most other introduced woody plants in its eventual negative ecological impact.

Euonymus alatus (Thunberg) Siebold—25193 (N). Introduced; fencerow; rare, but with the potential of becoming much more common.

Euonymus atropurpureus Jacquin—24873 (B), 25206 (F), 24670 (H), 24750 (M), 25153 (N), 24992 (R). Upland woods and disturbed habitats, common in fencerows; frequent.

Euonymus fortunei (Turcz.) Hand.-Maz.—24852 (B); 25049 (H), 24777 (M), 25109 (N), 25049 (R). Introduced; old dump sites and also establishing adventively (spread by birds). Not yet common in the study area but soon will be. When fully established, supplants the entire herbaceous stratum of deciduous forest.

Clusiaceae

Hypericum stragulum Adams and Robson (= *Ascyrum hypericoides* var. *multicaule* of some authors)—25276 (F). Other woody hypericums in Kentucky apparently are absent from the study area; Knobs only.

Cornaceae

Cornus amomum Miller var. *schuetzeana* (Meyer) Rickett—24839 (B), 25234 (F), 24809 (M). During this study, located only on the banks of the Ohio River and in Big Run Swamp, Fleming County.

Cornus drummondii C.A. Meyer—24878 (B), 25329 (F), 24643 (H), 25100 (N), 25001(R). Xeric woods, disturbed habitats, and fencerows; common.

Cornus florida L.—24890 (B), 25292 (F), 24703 (H), 24739 (M), 25090 (N), 25023 (R). Mesic woods and bluffs; widespread but nowhere common; being decimated by fungal pathogens (Harlow et al. 1996).

Nyssa sylvatica Marshall—25299 (F), 24636 (H), 24830 (M), 25068 (R). Mesic woods; occasional to rare in study area, except for Knobs of Fleming County.

Nyssa sylvatica Marshall var. *biflora* (Walter) Sargent—25226 (F). Rare; Big Run Swamp.

Ebenaceae

Diospyros virginiana L.—24921 (B), 25262 (F), 24600 (H), 24732 (M), 25129 (N), 25006 (R). Frequent in fencerows; also widespread but not common in mesic woods.

Elaeagnaceae

Elaeagnus umbellata Thunberg—25250 (F), 24702 (H), 24791 (M), 25107 (N), 24972 (R). Introduced; disturbed habitats; infrequent.

Ericaceae

Gaylussacia baccata (Wangenh.) K. Koch—Meijer, Setser, and Meade 1150 = MDKY #4630 (F). Xeric woods, infrequent; Knobs.

Kalmia latifolia L.—25345 (F). Upland woods, rare; Knobs.

Oxydendrum arboreum (L.) DC.—25303 (F). Upland woods; Knobs.

Vaccinium corymbosum L.—25344 (F). Upland woods, infrequent; Knobs only.

Vaccinium pallidum Aiton—25270 (F). Same habitats and localities as *Gaylussacia baccata.*

Vaccinium stamineum L.—25266 (F). Upland woods, frequent; Knobs only.

Fabaceae

Amorpha fruticosa L.—24841 (B), 24808 (M). In our study area, apparently confined to the banks of the Ohio River.

Lespedeza bicolor Turcz.—25205 (F), 25186 (N). Introduced; escaping from plantings in state-managed wildlife management areas.

Robinia pseudoacacia L.—24920 (B), 25295 (F), 24633 (H), 24781 (M), 25172 (N), 25080 (R). Very common in varied habitats and disturbed areas.

Fagaceae

Castanea mollissima Blume—W. Meijer, 15 Sep 1974, UKY #35813 (F). Introduced.

Fagus grandifolia Ehrhart—24854 (B), 25230 (F), 25089 (N), 25013 (R). Ravines and mesic slopes; rare in Bluegrass, common only in Knobs.

Quercus alba L.—24899 (B), 25311 (F), 24660 (H), 24713 (M), 25110 (N), 25004 (R). Mesic woods; common throughout.

Quercus bicolor Willd.—25201 (F). Upland swamp, rare; Knobs.

Quercus coccinea Muenchh.—24856 (B), 25265 (F). Extremely rare in Bluegrass; we discovered a population of only two mature trees in a pasture fencerow in Bracken County and noted no reproduction. Very common in xeric and submesic woods in the Knobs.

Quercus imbricaria Michaux—24934 (B); 25229 (F); 24588 (H), 24820 (M), 25177 (N), 24966 (R). Widespread but rare throughout our study area.

Quercus macrocarpa Michaux—25320 (F), 24623 (H), 24823 (M), 25162 (N), 25056 (R). Frequent in the south but progressively more rare northward in the area we studied.

Quercus montana Willd. (=*Q. prinus* L. of some authors)—25287 (F). Xeric south- and west-facing slopes and ridges; frequent in Knobs. The type of *Q. prinus* in the Linnaean herbarium may be of the lowland chestnut oak (=*Q. michauxii* Nuttall) instead of the upland chestnut oak, and the two names have been confused in the literature for many years (Hardin 1979). Since *Q. michauxii* and *Q. montana,* respectively, are unambiguous names, it is better to use them instead.

Quercus muhlenbergii Engelm.—24880 (B), 25195 (F), 24656 (H), 24757 (M), 25143 (N), 25041 (R). Upland habitats throughout; frequent.

Quercus palustris Muenchh.—24947 (B), 25258 (F), 24698 (H), 24789 (M), 25106 (N). Frequent only along the Ohio River and in Fleming County upland swamps; otherwise sporadic and occasionally escaping from cultivation.

Quercus rubra L.—24906 (B), 25288 (F), 24696 (H), 25102 (N), 24986 (R). Mesic uplands, usually on east- and north-facing slopes; occasional to rare.

Quercus shumardii Buckley—24870 (B), 25224 (F), 24631 (H), 24734 (M), 25138 (N), 25012 (R). Various habitats; common.

Quercus stellata Wangenh.—24871 (B), 25264 (F), 24666 (H), 24825 (M), 24977 (R). Upland woods and fencerows; occasional.

Quercus velutina Lamarck—24910 (B), 25278 (F), 24642 (H), 24716 (M), 25111 (N), 25069 (R). Upland woods; frequent.

Quercus ×willdenowiana Zabel—24692 (H). A hybrid, found in a fencerow, between *Q. velutina* Lam. and *Q. falcata* Michaux. We were unable to find the latter parent in the vicinity; however, considering the advanced state of habitat loss, it easily could have formerly occurred nearby.

Grossulariaceae

Ribes missouriense Nuttall ex Torrey and Gray—25357 (N). Canebrake, rare.

Hamamelidaceae

Hamamelis virginiana L.—25294 (F). Various wooded habitats; Knobs.

Liquidambar styraciflua L.—25259 (F). Various wooded habitats; Knobs. Plants of this taxon we noted along the Ohio River appeared to have been planted.

Hippocastanaceae

Aesculus flava Aiton—24835 (B); 25223 (F); 24814 (M). Confined to ravines and north-facing slopes along the Ohio River and its direct tributaries; also in mesic woods of Knobs.

Aesculus glabra Willd.—24855 (B), 25196 (F), 24614 (H), 24722 (M), 25173 (N), 25021 (R). Wooded slopes, disturbed habitats, and fencerows; common.

Hydrangeaceae

Hydrangea arborescens L.—24927 (B), 25291 (F), 24720 (M), 25176 (N), 25061 (R). Normally confined to mesic east- and north-facing bluffs along major streams; infrequent.

Philadelphus coronarius L.—25243 (F). Introduced; established and spreading on old roadcut; rare. Most other adventive populations of this genus in Kentucky probably should be referred to this taxon.

Juglandaceae

Carya cordiformis (Wangenh.) K. Koch—24887 (B), 25202 (F), 24649 (H), 24763 (M), 25142 (N), 25031 (R). Most wooded habitats; the most common hickory in our study area.

Carya glabra (Miller) Sweet—24891 (B), 25269 (F), 24676 (H), W. Meijer, 13 Jun 1969, UK #33801 (M); 25017 (R). Upland woods; infrequent to rare.

Carya laciniosa (Michaux f.) Loud.—24898 (B), 25328 (F), 24668 (H), 24712 (M), 25125 (N), 25014 (R). Various wooded habitats; frequent.

Carya ovata (Miller) K. Koch—24892 (B), 24635 (H), 25125 (N), Thieret 52747 in KNK (R). Infrequent to rare; most common near the border between Bluegrass and Knobs in Fleming County. Plants of this taxon in our region do not fit well the recent description given by Stone (1997). The apparent reason is that, throughout most of central Kentucky, introgression may be occurring between plants of this taxon and the following one.

Carya tomentosa (Poiret) Nuttall—24883 (B), 25222 (F), 24640 (H), 24824 (M), 25087 (N), 24989 (R). Upland woods and woods remnants; frequent to occasional.

Carya ovata × *Carya tomentosa*—24733 (M). As mentioned above, introgression between these two taxa is common in our region, producing various degrees of intermediacy. This is a collection that appeared to us to be truly intermediate, so we cite it as an unnamed hybrid.

Carya pallida (Ashe) Engler and Graebner—24860 (B), 25112 (N), 25062 (R). Upland woods and woods margins; infrequent.

Juglans nigra L.—24896 (B), 25280 (F), 24677 (H), 24730 (M), 25148 (N), 24923 (R). Various habitats; common. We did not observe any specimens of *J. cinerea* L., living or dead, in the study area.

Lauraceae

Lindera benzoin (L.) Blume—24876 (B), 25293 (F), 24650 (H), 24762 (M), 25088 (N), 25019 (R). Various disturbed, degraded, and intact habitats; one of the most common shrubs in this area of Kentucky.

Sassafras albidum (Nuttall) Nees—22419 (B), 25285 (F), 24647 (H), 24718 (M), 25114 (N), 25027 (R). Various habitats; common.

Magnoliaceae

Liriodendron tulipifera L.—24853 (B), 25305 (F), 24627 (H), 24717 (M), 25018 (R). Mesic woods; rare in Bluegrass, progressively more common eastward.

Malvaceae

Hibiscus syriaca L.—24761 (M). Introduced; escaped along roadside; rare, but to be expected more commonly in the future.

Menispermaceae

Menispermum canadense L.—24877 (B), 25246 (F), 24592 (H), 24760 (M), 25164 (N), 24998 (R). Various habitats, more frequent in highly disturbed situations, such as fencerows and rights-of-way; common.

Mimosaceae

Albizia julibrissin Durazzini—25216 (F). Introduced; possibly persistent after cultivation, or possibly an escape.

Moraceae

Broussonetia papyrifera (L.) Ventenat—24719 (M). Introduced; an escape into highly disturbed habitat.

Maclura pomifera (Raf.) C.K. Schneider—24859 (B), 25337 (F), 24684 (H), 24768

(M) 25156 (N), 25076 (R). Various disturbed habitats; common.

Morus alba L.—24948 (B), 25319 (F), 24669 (H), 24818 (M), 25182 (N), 25078 (R). Introduced; roadsides and other disturbed habitats; occasional.

Morus rubra L.—24904 (B), 25290 (F), 24679 (H), 24779 (M), 25161 (N), 25008 (R). Mesic slopes and alluvial terraces; infrequent, but more common eastward.

Oleaceae

Chionanthus virginica L.—25300 (F). Upland woods; occasional; Knobs.

Fraxinus americana L.—24902 (B), 25296 (F), 24667 (H), 24811 (M), 25171 (N), 25007 (R). Woodlands and woodland remnants; common.

Fraxinus pennsylvanica Marshall—24949 (B), 25204 (F), 24596(H), 24723 (M), 25137 (N), 25060 (R). Alluvial terraces and stream margins; common.

Fraxinus quadrangulata Michaux—24938 (B), 25325 (F), 24618 (H), 25141 (N), 24983 (R). Various wooded habitats but most common on south- and west-facing xeric woodlands and stream bluffs; frequent.

Ligustrum sinense Louriero—24851 (B), 24602 (H), 24804 (M). Introduced; escaped to waste places, highly disturbed habitats and alluvial woods. Most common near the Ohio River.

Ligustrum vulgare L.—24951 (B), 24785 (M), 25190 (N). Introduced; escaped to highly disturbed habitats. Most common in the Ohio River corridor.

Platanaceae

Platanus occidentalis L.—24941 (B), 25253 (F), 24630 (H), 24787 (M), 25149 (N), 25044 (R). Most common in low ground, but also in other situations; frequent.

Poaceae

Arundinaria gigantea (Walter) Chapman—25355 (N). Wooded ravine; extremely rare.

Ranunculaceae

Clematis virginiana L.—24954 (B), 25257 (F), 24700 (H), 24742 (M), 25175 (N), 25070 (R). Low ground along streams and woodland margins; infrequent.

Rhamnaceae

Rhamnus caroliniana Walter—25197 (F), 24743 (M). Deciduous woods and disturbed rights-of-way. Very rare in Bluegrass, infrequent in Knobs.

Rhamnus lanceolata Pursh—25200 (F), 24693 (H). Only two populations noted: one on a wooded alluvial terrace (Bluegrass), the other in highly disturbed upland habitat (Bluegrass-Knobs border).

Rosaceae

Amelanchier arborea (Michaux f.) Fernald—25297 (F). Deciduous woods, occasional; Knobs.

Crataegus calpodendron (Ehrh.) Medikus—24863 (B), Meijer, Setser, and Meade 1190 = MDKY #1190 (F), 24594 (H), 25097 (N), 25063 (R). Upland roadsides, blufftops, and woodland margins; infrequent.

Crataegus coccinea L.—25211 (F), 24612 (H), 25121 (N). Woodland margins and disturbed habitats; infrequent.

Crataegus crus-galli L.—25238 (B), 24685 (F), 24812 (M), 25126 (N). Upland disturbed sites and woodland margins; infrequent.

Crataegus flabellata (Bosc) K. Koch—25208 (F), 24590 (H), 25113 (M), 25064 (R). Upland disturbed sites and woodland margins; infrequent.

Crataegus mollis (Torrey and Gray) Scheele—24863 (B), 24678 (H), 24817 (M), 25158 (N). Mainly in fencerows and on blufftops; infrequent.

Crataegus pruinosa (Wendland) K. Koch—24862 (B). Disturbed woodland; rare.

Malus angustifolia (Aiton) Michaux—25341 (F), 25118 (N). Only two populations noted: open field (Bluegrass); low woods along creek (Knobs). Rare.

Malus coronaria (L.) Miller—24932 (B), 25247 (F), 24683 (H), 24815 (M). Upland woodland margins and fencerows; rare.

Malus sylvestris (L.) Miller (=*M. pumila* of some authors)—25318 (F), 24765 (M), 25152 (N), 24974 (R). Introduced; fencerows and other ruderal habitats; infrequent.

Physocarpus opulifolius (L.) Maxim.—G.F. Buddell II #2206, in KNK (B).

Prunus americana Marshall—24857 (B), 25245 (F), 24589 (H), 24714 (M), 25144

(N), 24984 (R). Forest remnants, disturbed woods, and fencerows; frequent.

Prunus cerasus L.—25219 (F). Introduced; adventive, adjacent to road right-of-way.

Prunus mahaleb L.—24935 (B), 24690 (H), 24745 (M), 25133 (N), 25034 (R). Introduced; roadcuts and rights-of-way; infrequent.

Prunus mexicana S. Watson—24905 (B), 24639 (H), 24715 (M), 25122 (N), 24981 (R). Forest remnants, disturbed woods, and fencerows; frequent.

Prunus munsoniana Wight and Hedrick—25214 (F). Ridgetop in deciduous woods, Mississippian Plateau (Knobs); rare.

Prunus persica (L.) Batsch—25213 (F), 24687 (H), 24806 (M), 25178 (N), 24963 (R). Introduced; fencerows and other ruderal habitats; infrequent.

Prunus serotina Ehrhart—24919 (B); 25304 (F), 24637 (H), 24775 (M), 25169 (N), 25042 (R). Most habitats; common.

Pyrus calleryana Decne.—24884 (B), 25209 (F), 24595 (H), 24816 (M), 25117 (N), 25059 (R). Introduced; roadsides, margins of blufftop woods; infrequent.

Rosa carolina L.—24858 (B), 25274 (F), 24659 (H), 24735 (M), 25099 (N), 25009 (R). Upland deciduous woods and glades; frequent.

Rosa multiflora Thunberg—24916 (B), 25283 (F), 24658 (H), 24786 (M), 25159 (N), 25035 (R). Introduced; most habitats, common. At present, the worst woody weed in our study area.

Rosa setigera Michaux—24895 (B), 24591 (H), 24741 (M), 25092 (N), 25075 (R). Fencerows, low rights-of-way; common.

Rosa virginiana Miller—24680 (H). This is apparently the first report of this species from the Bluegrass (Browne and Athey 1992). However, because Medley (1993) rejected the notion that the species occurs in Kentucky, this collection actually may represent the first verified occurrence of the species in the state. Fencerow; rare.

Rosa wichuraiana Crepin—24953 (B), 24601 (H), 24822 (M). Introduced; roadsides and fencerows; infrequent, but undercollected.

Rubus allegheniensis T.C. Porter—25308 (F). Various habitats, Knobs.

Rubus argutus Link—24881 (B), 25346 (F), 24675 (H), 24803 (M), 25150 (N), 2499 (R). Various habitats; common.

Rubus flagellaris Willd. (incl. *R. enslenii* Tratt.)—24634 (H), 24995 (R). Deciduous woods; infrequent, but undercollected.

Rubus occidentalis L—24866 (B), 25248 (F), 24674 (H), 24784 (M), 25165 (N), 24994 (R). Upland and lowland woods and various disturbed habitats; frequent.

Rubus trivialis Michaux—25331 (F), 25083 (R). Fencerows; rare.

Spiraea tomentosa L.—Meijer, Setser, and Meade #1223, in MDKY (F). Wooded upland swamp.

Rubiaceae

Cephalanthus occidentalis L.—24944 (B), 25236 (F). Margin of Ohio River backwater; upland swamp; rare.

Rutaceae

Ptelea trifoliata L.—25321 (F), 24607 (H), 25185 (N). Bluffs along major streams; common in habitat but absent elsewhere.

Zanthoxylum americanum Miller—24931 (B), 25198 (F), 24641 (H), 24737 (M), 25085 (N), 25000 (R). Xeric bluffs and slopes, usually south- or west-facing; common in habitat, absent elsewhere.

Salicaceae

Populus alba L.—24865 (B), 25194 (F), 24626 (H), 24725 (M), 25098 (N), 25065 (R). Introduced; spreading from cultivation at old home sites, fencerows, and ruderal habitats; occasional.

Populus deltoides Bartr. ex Marshall—24840 (B), 25340 (F), 24686 (H), 24795 (M), 24973 (R). Low ground; occasional to rare, nowhere common.

Populus grandidentata Michaux—25242 (F). Old roadcut; rare. Apparently absent from Bluegrass area.

Salix alba L.—25108 (N). Introduced; established along Brushy Creek.

Salix caroliniana Michaux—24848 (B). Backwater of Ohio River, apparently absent from other parts of study area.

Salix discolor Muhl.—J. Campbell, 16 May 1992, UKY (F).

Salix exigua Nuttall—24846 (B), 25240 (F), 24706 (H), 24797 (M), 25135 (N), 24971 (R). Open stream corridors; common.

Salix nigra Marshall—24942 (B), 25237 (F), 24705 (H), 24821 (M), 25135 (N), 24971 (R). Open stream corridors; occasional.

Salix sericea Marshall—25261 (F). Open, upland swamp; rare.

Simaroubaceae

Ailanthus altissima (Miller) Swingle—24955 (B), 25212 (F), 24604 (H), 24780 (M), 25130 (N), 25082 (R). Introduced; disturbed habitats (mature trees; seedlings are found in almost all habitats). Occasional, but obviously accelerating in its rate of naturalization.

Smilacaceae

Smilax glauca Walter—24861 (B), 25267 (F), 24645 (H), 25101 (N). South-and west-facing wooded slopes, fencerows; infrequent.

Smilax hispida Muhl.—24958 (B), 25279 (F), 24652 (H), 24759 (M), 25119 (N), 25071 (R). Most habitats; common.

Smilax rotundifolia L.—25302 (F). Various habitats; Knobs.

Staphylea trifolia L.—24930 (B), 25323 (F), 24608 (H), 24740 (M), 25086 (N), 25066 (R). Mesic woods; frequent.

Tiliaceae

Tilia americana L. var. *americana*—24888 (B), 25231 (F), 24615 (H), 24749 (M), 25127 (N), 24987 (R). Mesic woods; frequent.

Ulmaceae

Celtis occidentalis L.—24907 (B), 25301 (F), 24672 (H), 24773 (M), 25168 (N), 24999 (R). Various habitats, less frequent in the Knobs; one of the most common trees in this part of Kentucky.

Celtis tenuifolia Nuttall (= *C. occidentalis* var. *georgiana* of some authors)—25330 (F), 24599 (H), 24965 (R). Upland xeric habitats, fencerows; infrequent.

Ulmus americana L.—24960 (B), 25256 (F), 24663 (H), 24805 (M), 25157 (N), 25043 (R). Various upland and low habitats; common.

Ulmus pumila L.—24843 (B), 24792 (M). Introduced; adventive in counties bordering the Ohio River.

Ulmus rubra Muhl.—24900 (B), 25249 (F), 24691 (H), 24766 (M), 25192 (N). Mesic wooded and disturbed slopes, stream bluffs; frequent.

Ulmus thomasii Sargent—24616 (H). Wooded stream bluff; rare.

Viscaceae

Phoradendron serotinum (Raf.) Johnst.—Thompson and Thompson #89-150, in KNK (B), Thompson and McLaughlin #88-3217, in MDKY (F), 24620 (on *Ulmus thomasii,* see above)(H), Thompson #88-3223, in KNK (M), Thompson and Denton #89-3015, in MDKY (R). Less frequently encountered northward.

Vitaceae

Ampelopsis cordata Michaux—24849 (B), 25046 (H), 24727 (M), 25046 (R). Streambanks, low open ground, and fencerows; sometimes frequent but rare or absent in Knobs.

Parthenocissus quinquefolius (L.) Planchon—24922 (B), 25316 (F), 24673 (H), 24752 (M), 25163 (N), 25016 (R). Most habitats; common.

Vitis aestivalis Michaux—24911 (B), 25317 (F), 25053 (H), 24997 (R). Roadsides and dry woods; common in Knobs, rare in Bluegrass.

Vitis riparia Michaux—24794 (M). Low ground along Ohio River; rare or absent elsewhere.

DISCUSSION

Habitats

Before embarking on this study, we were aware that most of the study region had a long history of intensive post-settlement land use. However, we were frankly surprised at the present extent of its effects. Most natural habitats in this region have been completely destroyed or degraded beyond recognition. Even though one does not encounter extensive row crops in this part of the Bluegrass, most of the uplands in this rolling country have been completely cleared, or only remnant, highly disturbed, young-aged woodlots remain. Downslope from uplands, where steeper terrain often militates against row cropping, land is most often relegated to pasture. Cattle (and, we suspect, very high populations of white-tail deer, *Odocoileus virginianus*) range through forested slopes and small creek bottoms, fenced off only from dwellings and roadways. As a result, most of the native herbaceous forest flora has been eliminated, woody plants do not regenerate naturally, and exotic species (such as *Lonicera maackii* and *Rosa multiflora*) are favored over natives. Oak regeneration has practically been eliminated in most of this part of the northern Bluegrass; scarlet oak (*Quercus coccinea*) probably will disappear from this part of the Bluegrass within the near future.

In situations such as this, highway rights-of-way and fencerows sometimes act as refugia for elements of the flora. However, in this part of Kentucky, this limited habitat is under frequent assault from the heavy application of herbicides along public roadways. Typically, this results in the elimination of most herbaceous and seedling woody dicots, not only along the roadway but as far as the sprayer can reach into the forest, and the invasion and herbaceous stratum dominance of species such as *Festuca* spp. and *Phalaris arundinacea* are encouraged. In other words, herbicide spraying is eliminating one of the very few habitats remaining in the Bluegrass for native plants. It is a purposeful, all-out assault by the State on its native plants.

As a result of these land-use patterns and prolonged exclusion of fire as an environmental factor, habitats of high quality in our study area were few and far between. In our opinion, the remnant site we encountered (other than Quiet Trails Nature Preserve [Harrison Co.], within which we did not collect) with highest natural value was within Clay Wildlife Management Area in Nicholas County. In our opinion, portions of Clay Wildlife Management Area should be managed as a natural area to protect what has been lost elsewhere in the region. In addition, we recommend that all remaining forested steep bluffs encountered along the Licking River and its major tributaries should receive protection. Without these remnant habitats, a significant percentage of the native woody species in this region would vanish entirely.

Distribution Patterns

We feel our study area is large enough to indicate some possible geographic distributional patterns of woody plant occurrence but too small to produce definitive evidence. However, four distributional patterns pertinent to the woody flora have emerged within the study area as a result of the evidence we compiled. These distributional categories are (1) an apparent distributional discontinuity between the northern Bluegrass and northern Knobs; (2) plants whose distribution seems related to the Ohio River corridor; (3) noteworthy rarities; and (4) significant weeds.

Category 1. Within the area we studied, it is apparent that there is a sharp distributional divide between the Bluegrass and Knobs. The following species occur in the Knobs but appear to be entirely missing from the Bluegrass. Plants present in the Knobs and absent from the Bluegrass (during this study) include all species of *Ericaceae* (six species), *Acer rubrum, Amelanchier arborea, Aralia spinosa, Betula nigra, Chionanthus virginica, Hamamelis virginiana, Liquidambar styraciflua, Hypericum stragulum, Nyssa sylvatica* var. *biflora, Pinus* (three species), *Populus grandidentata, Prunus munsoniana, Quercus montana, Rosa palustris, Rubus allegheniensis, Salix sericea, Smilax rotundifolia,* and *Viburnum acerifolium.* This means that more than 19% of native woody plant taxa occurring in the Knobs apparently do not occur in the adjacent northern Bluegrass. This is a significant discontinuity; reasons for it are hypothetical. One possible explanation could relate to edaphic factors, which affect mycorrhizae; the latter are known to be favored by acid soil. Members of Ericaceae and Pinaceae will grow if planted in the northern Bluegrass, but perhaps germination and establishment are selected against in Bluegrass soils. Also, it is well known to nurserymen that some species undergo mineral deficiency stress in dry alkaline soils; *Acer rubrum* is one of those species. We hypothesize that the combination of periodic drought, conditions unfavorable to mycorrhizae, and fire may have been major factors that prevented the establishment of seed sources in the Bluegrass, without which sustaining populations of some plants could not persist. One additional word about this distributional discontinuity is that, if one were to include the Cumberland Plateau (not far to the east of the study area), the floristic discontinuity becomes much more striking (includes *Ilex* spp., *Magnolia* spp., etc.). This issue might be a fruitful possibility for autecological investigations.

Category 2. A second recognizable group of woody plants is composed of those that are either confined to the Ohio River corridor or are found only in the Knobs and Ohio River corridor. As we define it here, the Ohio River corridor includes the Ohio River bottomlands, adjacent bluffs, and small streams draining directly into the Ohio River. Plants apparently confined closely to the Ohio River in our study area include *Amorpha fruticosa, Physocarpus opulifolius, Rhus typhina, and Salix caroliniana.* Those associated with the Ohio River and the Knobs but not found in the Bluegrass interior include *Aesculus flava, Alnus serrulata,* and *Cornus amomum* var. *schuetzeana.* This physiographic feature (i.e., the river corridor) may actually serve as a migration pathway for some species around the apparent barrier of the northern Kentucky Bluegrass region.

Category 3. Plants that are rare in the study area include those that are confined to particular habitats, as well as those that are in an attenuated portion of their ranges. Plants we would single out in this category include several plants confined to steep or gladelike bluffs (*Bignonia capreolata, Rhus aromatica, Ulmus thomasii*); those near the edges of their ranges (*Malus angustifolia, Nyssa sylvatica* var. *biflora, Prunus munsoniana, Quercus coccinea, Rhamnus lanceolata, Rosa virginiana,* and *Ulmus thomasii*).

Perhaps the most surprising rare taxon we encountered is *Arundinaria gigantea.* A few early informal accounts waxed eloquent on the extensive canebrakes in Kentucky, and these accounts seem to have been repeated endlessly by later writers. Perhaps it was true at one time. However, at the present time in our study area, *Arundinaria* is among the rarest of woody plants. We extensively but fruitlessly searched for it and even offered rewards for its discovery. Eventually, Dr. Wendell Kingsolver of Nicholas County took the senior author to a single population on his land. According to him, cane in the northern Bluegrass was once widespread but now has been reduced to a few small, isolated populations along main stem of the Licking River by a combination of grazing by cattle and long-time use of the stems for "jig poles," or throw-away, temporary fishing poles. Kingsolver (pers. comm.) stated that protection of the small (<2 ha) canebrake on his land from cattle grazing and pole collecting has allowed it to increase considerably in area, and ramets have been used to re-establish cane in another location where an extensive canebrake was completely extirpated.

Category 4. On the whole, we determined that 11% of the woody plant taxa of this region is not native. (See Table 1.) Many of these plants are not especially noticeable weeds at the present time. One of them (*Thuja orientalis*) is reported herein for the first time as an escape in Kentucky. Others (not included in our statistics) are plants whose native ranges are becoming obscured because they are both native and escaped from cultivation (e.g., *Juglans nigra, Liriodendron tulipifera, Maclura pomifera,* and *Quercus palustris*).

However, there are some significant exotic weeds and, based on the senior author's personal experience, few of these have reached their zeniths. The impact of most of these will increase with time, but some are more aggressive invaders than others. Non-native exotics escaped in our study area include the following (those marked with an asterisk were vouchered from a minimum of five counties): *Ailanthus altissima,* Albizia julibrissin, Berberis thunbergii, Broussonetia papyrifera, Celastrus orbiculatus, Elaeagnus umbellata,* Euonymus alatus, Euonymus fortunei,* Hedera helix, Hibiscus syriaca, Lespedeza bicolor, Ligustrum sinense, Ligustrum vulgare, Lonicera japonica,* Lonicera maackii,* Malus sylvestris, Morus alba,* Philadelphus coronarius, Populus alba,* Prunus cerasus, Prunus mahaleb,* Prunus persica,* Pyrus calleryana,* Rosa multiflora,* Rosa wichuraiana, Salix alba, Ulmus pumila,* and *Vinca minor.* From our field observations, *Lonicera japonica* and *Rosa multiflora* have the greatest negative ecological impact at present. However, *Ailanthus altissima, Celastrus orbiculatus, Euonymus fortunei,* and *Lonicera maackii* are showing signs of rapid establishment and have the potential for very significant negative impacts within a few years. One omission readers may note is *Paulownia tomentosa* (Thunb.) Steudel; though it appears not to be established in the study area yet, doubtless that will happen soon.

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Effects of Fish on Zooplankton Community Structure in Chaney Lake, a Temporary Karst Wetland in Warren County, Kentucky

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ABSTRACT

Chaney Lake is an ephemeral karst lake in southern Kentucky (USA). Unlike most ephemeral lakes, Chaney often contains fish that can enter the lake through the underlying Lost River drainage system. The effects of introduction of golden shiners (*Notemigonus crysoleucas*) on zooplankton in Chaney were examined for a 2-week period in June and July 1997. Twelve fish were transplanted from an isolated region of the lake into each of three enclosures in an area of the lake where no fish had been observed. Three additional enclosures served as fish-free controls. Zooplankton samples and water chemistry and nutrient data were taken every 4 days. Water chemistry and nutrient data showed no significant differences in the measured parameters between enclosures with fish and those without fish. *Bosmina* and *Acanthocyclops* showed decreases in population growth rates in the presence of fish. The fish had no effect on the growth rates of the smaller zooplankton present such as the rotifers. Vertebrate predation in systems like Chaney Lake may pose significant ecological challenges for organisms adapted to temporary habitats.

INTRODUCTION

Fish can be important determinants of zooplankton abundance, species structure, and productivity in aquatic systems. Since the early work of Hrbacek et al. (1961) there have been numerous studies documenting the impacts of fish on zooplankton communities. Removal of zooplanktivorous fish from lakes has been shown to increase the densities of herbivorous zooplankton with concomitant effects on the phytoplankton (Carpenter et al. 1985, 1987; Vanni et al. 1990). This work has prompted research in the use of fish in "biomanipulation" to aid managers in controlling water quality in lakes (Shapiro and Wright 1984). There has been less research conducted on the effects of fish on zooplankton in wetland or forested lake communities, although fish have been shown to have significant effects on zooplankton in shallow, eutrophic, lakes that may be similar in many respects to wetlands (Hanson and Butler 1990). In a study of semipermanent Minnesota wetlands, Hanson and Riggs (1995) found that densities, biomasses, and taxa richness of zooplankton were significantly lower in wetlands that contained fish as opposed to similar ponds which did not contain any fish. In a study of another Minnesota prairie lake, a fish kill resulted in shift in zooplankton species composition from *Bosmina* and *Chydorus* to the larger *Daphnia galeata* and *D. pulex* (Hanson and Butler 1994).

Wetland areas may provide more refuges to zooplankton from fish predation than the open water column of a lake.In a pond-enclosure experiment where the density of vegetation was controlled, perch did not consume as much zooplankton biomass when vegetation was present in the enclosures as when vegetation was absent (Diehl 1992). In their study of a coastal marsh along Lake Erie, Kreiger and Klarer (1991) found that some copepods and cladocerans were more abundant near the sediments or near macrophytes than in the open-water column, which is consistent with earlier work suggesting that vegetation can provide an important refuge for zooplanktors from fish predation (Timms and Moss 1984).

While such biotic interactions between fish and zooplankton are important in structuring planktonic communities in permanent aquatic systems, in most temporary or ephemeral pond systems zooplankton are not subject to fish predation, although other vertebrates such as amphibians may have strong effects on zooplankton assemblages (Wilbur 1997). Indeed, taxa such as the large branchiopod Crustacea are thought to be successful in temporary systems because fish are often excluded from these habitats (Kerfoot and Lynch 1987). Organisms inhabiting ephemeral water bodies

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typically have life histories and ecological strategies that are synchronized to the hydrology of their habitat (reviewed in Wiggins et al. 1980) and that do not necessarily give these organisms any advantage in responding to predation from fish. In most transient water habitats, the threat of fish predation would be exceedingly small; in some ephemeral karst lakes, however, fish predation may be an important force structuring the zooplankton community.

Karst geology is characterized by extensive caves, sinkholes, sinking streams, and springs. Because of the many conduits leading into the subsurface in well-developed karst landscapes, surface water may be directed rapidly into the groundwater areas through a sinkhole, may rise again at a spring, and then sink into the subsurface again as a sinking stream. These points of exit and entrance of water are called estavelles. In many karst landscapes, standing surface water is uncommon, but variations in local geology can produce ephemeral karst lakes and wetlands such as Chaney Lake in south-central Kentucky. Chaney Lake is a 68-hectare state nature preserve located about 10 km south of Bowling Green in Warren County, Kentucky. The lake area is a shallow depression that is connected by fissures (estavelles) in the subsurface rock to the Lost River Cave system, which has a drainage basin of about 233 km^2. The lake is formed because of the Lost River Chert formation, which overlays the limestone under the lake and prevents the rapid return of water to the subsurface except where estavelles are located. When the capacity of the Lost River Cave system is exceeded during periods of high precipitation, groundwater enters Chaney Lake via the estavelles and also through one intermittent surface stream on the south edge of the preserve. As the water levels in the Lost River drop, water may leave the lake through the estavelles as well, leaving large numbers of smaller, isolated pools behind. The lake usually holds water from December through August, although from May on most of that water is in small pools (Jack, personal observation).

Historically, karst wetlands such as Chaney Lake were very important aquatic habitats in western Kentucky because they provided an important source of standing water in a terrain that had little surface water. Chaney Lake and another nearby karst lake, Rich Pond, host huge numbers of migrating birds in the spring and may be an important foraging area for a variety of waterfowl on their spring migrations (Mason, personal communication). Chaney Lake contains a variety of zooplankton species, including common ephemeral pond taxa such as the fairy shrimp *Streptocephalus*. However, the same estavelles that deliver water to support these communities can also serve as conduits for vertebrates such as the spring fish, *Chologaster agassizi*, to enter the lake. If fish can enter Chaney Lake, they may have a strong impact on zooplankton densities and community structure.

In early June 1997, a population of golden shiners (*Notemigonus crysoleucas*), which may have entered Chaney Lake via estavelles, was found in an isolated pool in the northeast corner of Chaney Lake. These fish were transplanted to experimental enclosures in another section of the lake to assess the effect of fish on the zooplankton communities in Chaney. We hypothesized that the fish would select the largest zooplankton species in the water column and, in turn, would cause a decrease in population growth rates of these larger species. We expected that the smaller zooplankton species such as rotifers would have no significant response to the fish or that they would increase in numbers if they are released from competition for resources with, or predation from, the larger macrozooplankton (see Gilbert 1988; Jack and Gilbert 1997).

MATERIALS AND METHODS

The study was conducted from 19 Jun 1999 to 1 Jul 1997 in a marsh area in the southeastern portion of Chaney (see Kelley et al 2000). This area was chosen as the study site because no fish had been observed there and it was unlikely to dry during the period planned for the experiment. The dominant vegetation in the marsh was buttonbush (*Cephalanthus occidentalis*), aquatic plants such as *Polygonum* sp. and a liverwort in the genus *Riccia*. The higher ground around the marsh area is ringed by tree species such as swamp white oak (*Quercus bicolor*), red maple (*Acer rubrum*) and sycamore (*Platanus occidentalis*). Large trees are not present in the marsh itself, perhaps because this part of Chaney consistently holds water for most of the year (>7 months in 1995–1998).

Six 1-m³ enclosures were constructed using PVC piping for frames and plastic for the sides. The enclosures were then placed in the marsh, enclosing the water column and the associated zooplankton. They were anchored into the sediment of the marsh and were open at the top and at the bottom. Three enclosures were randomly selected to hold 12 fish each, with the other three serving as controls. The fish were caught by sweeping a net in the pool containing the fish and moving the fish into the appropriate enclosures in the marsh. These stocking densities were about ½ the estimated density of the fish in the original pool. This was determined by visually assessing the numbers of fish in the source pool and then taking transects through the pool to determine average depth and diameter, which were then used to estimate pool volume. Invertebrate and water chemistry samples were taken on the first day of the experiment and every 4 days afterward in each of the six enclosures for the duration of the project. Depth, turbidity, specific conductivity, temperature, pH, dissolved oxygen, and percent dissolved oxygen were recorded using a YSI 6250 multiprobe. One-liter nutrient grab samples were also taken in acid-washed bottles to measure nitrates, ammonia, and soluble reactive phosphorous using a Hach DREL 6000 water analysis kit. Nitrate was measured by the Cadmium Reduction method; ammonia was determined using the Nessler method; and soluble reactive phosphorus was measured using the Hach Phosver 3 method. Invertebrate sampling was conducted using a 7-cm-diameter coring device. Two 5-liter core samples were taken from each enclosure on each sampling date and filtered through a 20-μm mesh sieve. The material collected was then washed into a container and preserved in 90% ethanol.

All samples were counted in the laboratory by using an Olympus SZH 10 dissecting microscope. The samples were counted in their entirety and the dominant taxa (>95% of numerical abundance) were identified down to the lowest practicable taxon (usually genus). Population growth rates were calculated for the dominant taxa from the first and last experimental dates using the equation, $r = \ln N_f - \ln N_0 t^{-1}$, where r is equal to the population growth rate, N_f is equal to the final sampling date, No represents the beginning sampling date, and t stands for the total number of days in the experiment (Jack and Gilbert 1993). A Student's *t*-test was used to compare growth rates in the fish and fishless enclosures. A repeated measures ANOVA was calculated using SYSTAT version 7.0 to assess changes in the physical parameters in the enclosures.

RESULTS

The data met the assumptions of ANOVA so transformation was not needed before the data could be analyzed. Water chemistry and nutrient analysis data indicated no significant differences ($P > 0.07$) in measured parameters between treatments over time. The average temperature for all enclosures was 23.4 ± 0.84°C and the pH in the enclosures averaged 5.93 ± 0.57 (all data are presented as mean ± (standard errors). Turbidities were quite variable in all enclosures (39.4 ± 23.2 and 40.0 ± 24.3 for fish and non-fish respectively) and were higher after storm events. Dissolved oxygen levels ranged from just under 1 mg liter^{-1} to 3.3 mg liter^{-1} but there were no differences in oxygen levels between treatments. Average nitrate, ammonia and soluble reactive phosphorus concentrations were not different between treatments ($P > 0.15$; Figure 1).

The fish added to the enclosures had an initial average size (mouth to base of caudal fin) of 1.95 ± 0.21 cm; the average length at the end of the experiment was 2.46 ± 0.06 cm. The macrozooplankton assemblage in the marsh was dominated (>90%) by *Bosmina* sp. and *Acanthocyclops* sp., with smaller numbers of *Ceriodaphnia* sp., *Daphnia* sp., and at least two species of ostracods. The ostracods were similar in size and were grouped together for the purposes of the analysis. One isopod (*Caecidotea* sp.), one amphipod (*Hyalella azteca*), and at least one water mite (Hydracrina) species occurred in the samples. The latter three groups were considered to be accidentals in the plankton and were not included in the analysis. The microzooplankton assemblage was primarily composed of rotifers, with *Monostyla* sp., *Euchlanis* sp. and *Ascomorpha* sp. as the numerical dominants (>78%). There were also one species each of *Branchinous*, *Keratella, and Lecane*, and two *species of Polyarthra* species present in some samples. We

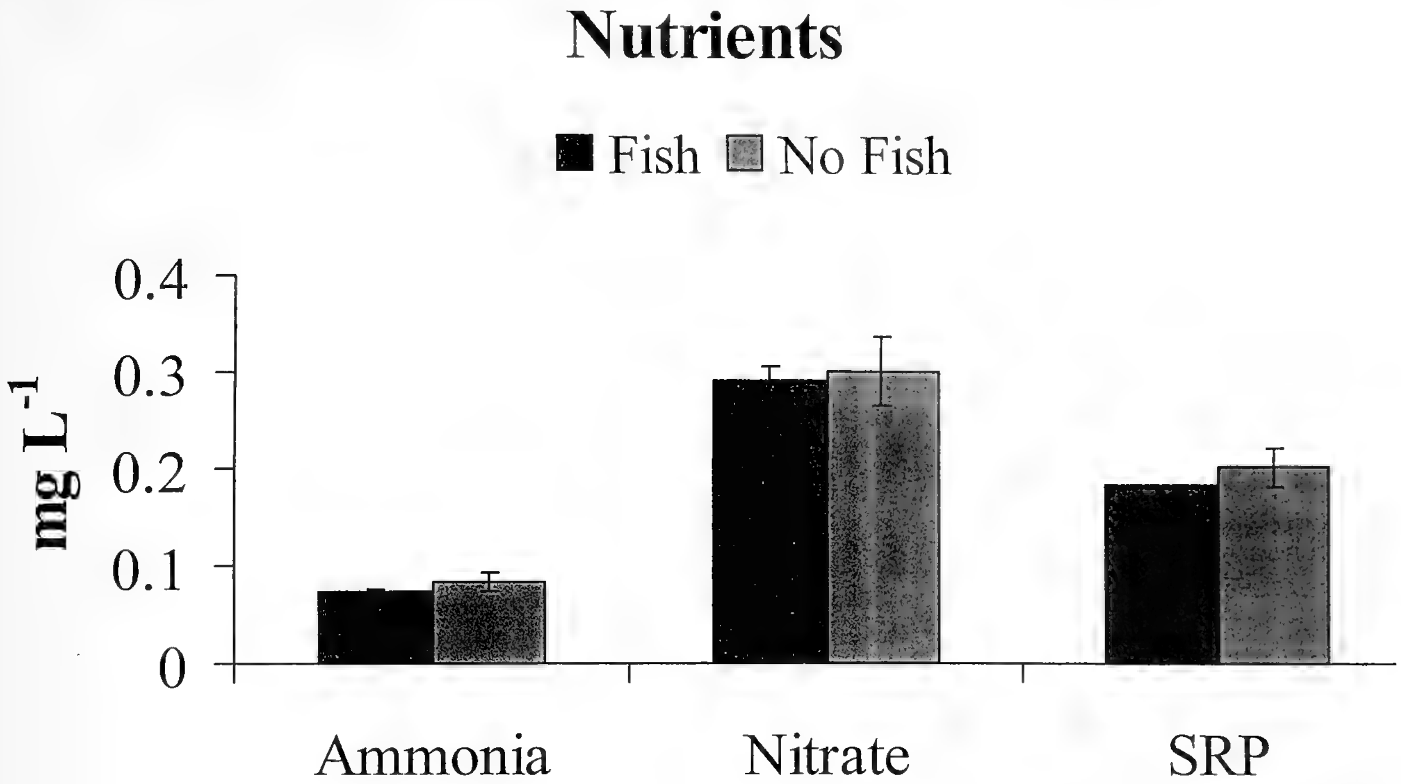

Figure 1. Ending concentrations of ammonia, nitrate, and soluble reactive phosphorous (SRP) in fish and fishless enclosures in Chaney Lake, Warren County, Kentucky (19 Jun 1999–1 Jul 1997). Bars show means and standard errors.

did not find any identifiable protists in our samples, but our filtering and fixation procedure may have prevented adequate sampling and recognition of these small organisms.

The presence of fish in the enclosures negatively affected the larger invertebrate taxa but showed no effect on the smaller taxa. The fish negatively affected the *Bosmina* sp. and the *Anthocyclops* sp. growth rates ($P < 0.006$; Figure 2). Ending mean densities of Bosmina were significantly higher in the fish-less enclosures (43 individuals liter^{-1}) compared to the fish enclosures (5.3 individuals liter^{-1}). *Acanthocyclops* sp. growth rates and ending mean densities were significantly higher in enclosures without fish (33 individuals liter^{-1}) than in enclosures with fish (7.3 individuals liter^{-1}). Ostracods as a group had a positive population growth rate when the fish were present and a negative growth rate without fish, but there was no significant difference between the two treatments ($P = 0.07$).

The presence of fish had no significant effect ($P > 0.07$) on the population growth rates of the three dominant rotifer species-*Ascomorpha, Euchlanis,* and *Monostyla* (Figure 3); however the densities of both *Euchlanis* and *Ascomorpha* decreased over time in all of the enclosures. Density of *Monostyla* sp. increased nearly 10 times over the same time period in all enclosures.

DISCUSSION

Our results confirmed that fish predation can affect aquatic invertebrate community structure in Chaney Lake.

Physical factors and nutrients assayed were not significantly different, so these factors probably did not contribute to the response of the zooplankton to fish. In enclosure experiments the effects of fish are sometimes the result of indirect mechanisms. Ammonia excreted by fish, for example, may enhance algal growth or the fish may feed on the algae, competing with the zooplankton. The golden shiners, however, are zooplanktivorous at this size (R. Hoyt, pers. comm.), and we found no differences in nutrient concentrations between the two treatments. The population growth rates we reported for our organisms were somewhat low compared to the instantaneous growth rates of related taxa in other ephemeral systems (Taylor et al. 1989), but this may be a reflection of a more constrained resource base in Chaney Lake.

Our data support the conclusion that fish predation in the enclosures was driving the suppression of large zooplankton in our study.

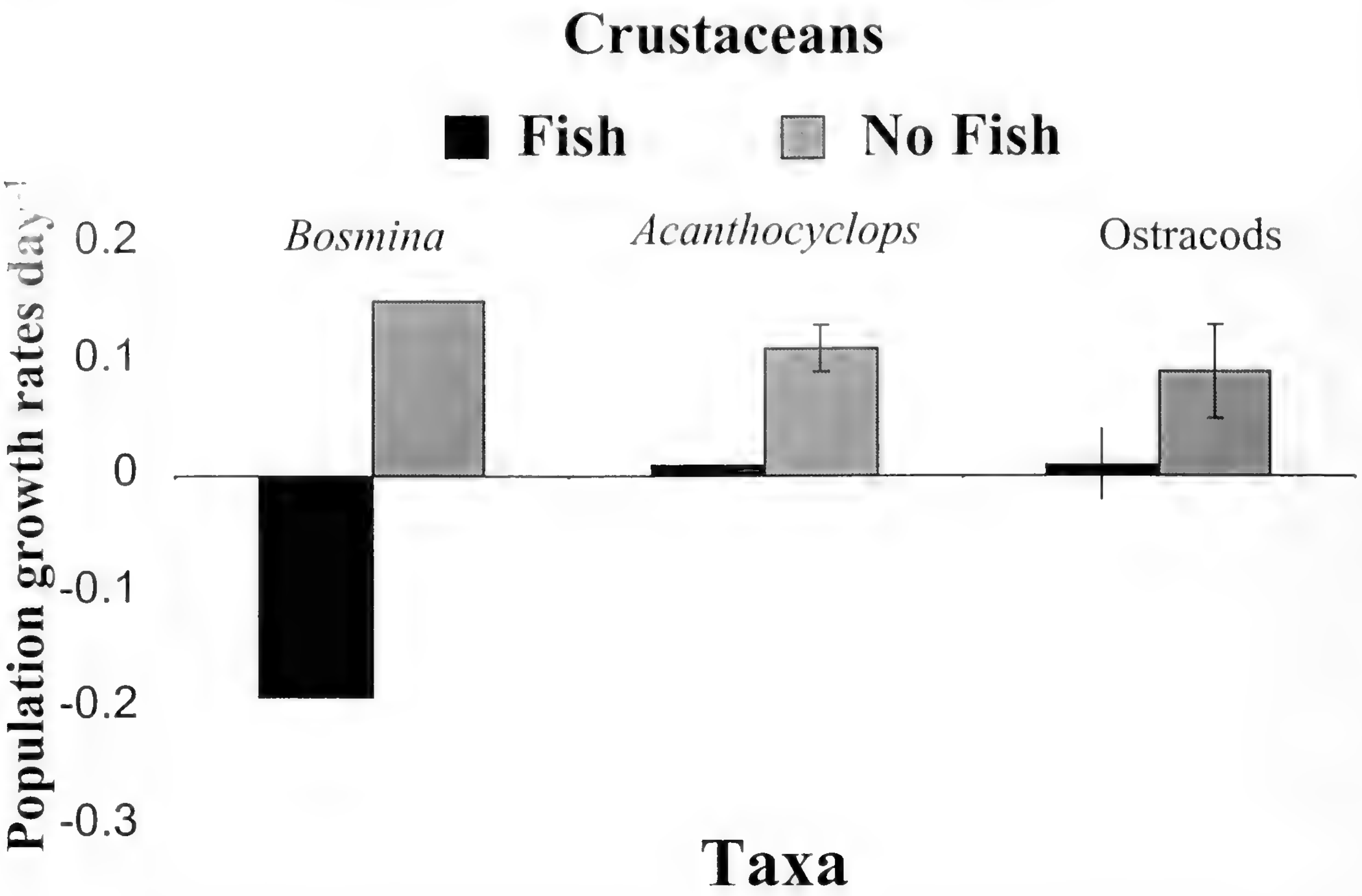

Figure 2. Population growth rates of the dominant crustacean species in fish and fishless enclosures in Chaney Lake, Warren County, Kentucky (19 Jun 1999–1 Jul 1997). Bars show means and standard errors.

Bosmina are not typically considered very vulnerable to fish predation because of their small size compared to other crustaceans, and many cyclopoids have well-developed escape responses that they may use to avoid fish predation. As the largest common zooplankton prey in the enclosures, however, one would expect that visually foraging fish would focus on *Bosmina* and the *Acanthocylops*. The ostracods were not significantly affected even though their mean size in the enclosures was comparable to that of *Bosmina* (0.65 vs. 0.44 mm, respectively). Ostracods are often found in association with vegetation or in benthic areas, where the golden shiners are unlikely to forage successfully on them. The ostracods present in our samples may not have been common in the plankton but may have been captured when the corer displaced them from the vegetation or the bottom.

Schneider and Frost (1996) found that in some cases the suppression of *Daphnia* in temporary ponds was associated with an increase in rotifer densities and taxon diversity. We did not see the increase in rotifer densities that we expected would occur once the macrozooplankton numbers were reduced; increases and decreases in rotifer numbers occurred across all enclosures regardless of treatment (see Results). This may indicate that the larger zooplankton are not significant predators on or competitors with the rotifers during this period in Chaney or that the rotifers were being more strongly limited by resource levels or other physiochemical factors in the lake. Previous research has indicated that small cladocerans like *Bosmina* are generally not effective predators on rotifers (reviewed in Gilbert 1988). The high densities of cyclopoid copepods in our study were also lower than those reported by Schneider and Frost (1996) in their study systems, so the impact of these crustaceans on the rotifers may have been too low to elicit a "release response" when the cyclopoid densities were reduced. The general increases and decreases in rotifer densities could also be the result of an unidentified "enclosure effect" affecting the rotifers. However, since this effect was expressed across all of the enclosures independently of treatment it should not affect our

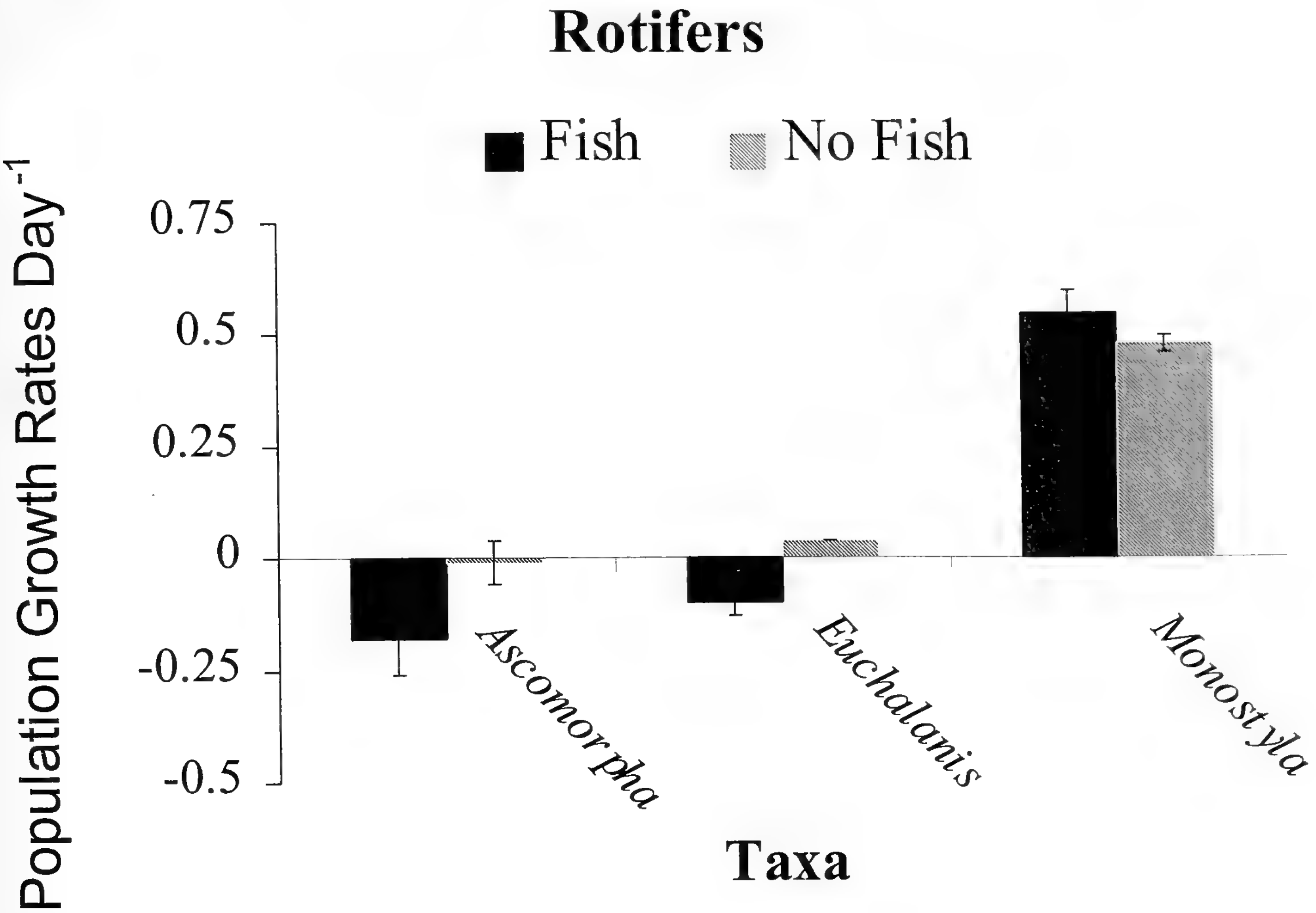

Figure 3. Population growth rates of the dominant rotifer species in fish and fishless enclosures in Chaney Lake, Warren County, Kentucky (19 Jun 1999–1 Jul 1997). Bars show means and standard errors.

interpretation of the fish effects in these enclosures.

The introduction of fish can have a profound impact on a system like Chaney. Early in the year, the entire Chaney basin is full, but as the year progresses it often dries to numerous smaller and disconnected ponds. If fish like the golden minnows are trapped in these pools, they could conceivably remove all of the large zooplankton from a particular pool. Many of the rotifers and crustaceans in these small pools appear to have multiple generations before they produce diapause eggs. If fish are introduced to a pool and severely reduce macrozooplankton densities, this could constrain the next year's recruitment in that pool. These pools may be colonized by zooplankton from other areas during periods of high water or there may be diapause eggs from previous years that could hatch, but that would be dependent on the vagaries of water level and on the natural histories of the organisms involved. If there are localized ecotypes adapted for the particular conditions in a pool or a closely associated group of pools, any unique genetic information in that population's gene pool may be lost as a result of fish predation. This information would probably not be replaced by colonists from other areas.

The path by which the fish enter Chaney may also be important. It is clear that fish may enter Chaney by the estavelles, but it may also be possible that they could enter the lake via overland flow during flood events. The area around Chaney contains at least one farm pond that may become connected to the lake during very high rainfall events. This would greatly expand the pool of potential fish colonists as fish that would be unable to survive in or travel through the Lost River system could enter Chaney in this manner. Very high densities of fish could be introduced this way; they could have an impact on the waterfowl and other vertebrate groups (e.g., amphibians) that use Chaney as breeding or feeding ground. Previous studies have already documented that waterfowl and fish are competitors for invertebrate prey in other wetlands (Hanson and

Riggs 1995), and that the presence of fish may reduce the prey available to birds that rely on Chaney as a foraging area during their spring migrations.

SUMMARY

Hydrology has long been identified as an important factor impacting organisms in ephemeral lakes and pools. In Chaney, however, fish may be present in even small pools with short duration since they may colonize the lake during the high flood period when the whole basin is inundated.

Our data indicate that fish predation has significant effects on zooplankton community structure in Chaney Lake, but the impact of these effects on ecosystem level processes such as nutrient cycling and microbial activity remains unexplored. Temporary habitats like Chaney provide tremendous natural laboratories for investigating ecological processes at a number of different scales. In karst terrenes in particular, these lakes probably have landscape-level effects on water quality and transport as well as local importance as centers for aquatic biological production and biodiversity. With many of these lakes threatened by development it is crucial that we continue to study these unique systems so that better management and preservation strategies can be devised to preserve the ecological integrity of these remarkable habitats.

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A Historiography of Archaeological Research in the Mammoth Cave Area of Kentucky: 1824–2000

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ABSTRACT

Archaeological interest in the Mammoth Cave area of Kentucky has been ongoing since the early 19th century, primarily because of the unique preservation offered at the underground cave sites. In this paper I examine almost 200 years of archaeological research conducted in the area. The paper loosely adheres to historical divisions first presented by Schwartz and later by Willey and Sablof.

INTRODUCTION

Examination of the history of archaeological study in the Mammoth Cave region of south-central Kentucky reflects parallel development with the growth of archaeology in North America (Schwartz 1967; Willey and Sabloff 1993), but it also demonstrates why additional intensive and systematic archaeological study should to be conducted in this very significant archaeological region. In this paper I provide an historical overview of archaeological research that has taken place in and around Mammoth Cave National Park. The paper loosely adheres to historical divisions first presented by Schwartz (1967) and expanded by Willey and Sabloff (1993).

The Speculative Period: Pre-1915

One of the earliest archaeological records pertaining to the central Kentucky karst area was written in 1824 by Constantine Samuel Rafinesque (1824). Rafinesque was deeply interested in prehistoric remains of the Ohio Valley (Stout and Lewis 1995:83–90). According to Col. Bennett Young (1910:18), Rafinesque claimed to have located 148 ancient sites (settlements) and 505 monuments in a 41-county area of Kentucky, speculating as with other early 19th century naturalists about the origin of these "natural" curiosities. Rafinesque's entry for the central Kentucky karst lists "shell mounds along Green River and mummies in caves."

Following Rafinesque's initial inquiry into Kentucky's prehistory, there appears to be an absence of related literature about the antiquities of the area. This is not to say that interest in antiquities had died; it had not. According to Col. Bennett Young (1910), increased farming activity and, in general, disruption of the land due to population growth, caused an escalation in destruction and looting of prehistoric sites. By 1870, the collecting, selling, and smuggling of antiquities in Kentucky was a major profession. Although the Mammoth Cave area is known mostly for its large cave system, the archaeological contents of the area offered a variety of artifacts and desiccated human remains for collecting and selling. Finds, such as Fawn Hoof in 1813, Scudder's Mummy in 1814, Little Al in 1875, and Lost John in 1935, helped make the Mammoth Cave area famous (Meloy 1968). During the mid-19th and early 20th centuries, many individuals explored nearby cave systems looking for mummies and Indian relics to sell (see Young 1910). Unfortunately, this dilettantish pastime stopped only in those caves that came under the protection of the National Park Service (NPS) after 1940 (e.g., Salts, Mammoth, Longs, Bedquilt, and Lee caves); even then, infrequent looting of caves within the National Park still occurred.

The earliest historic date known from inside Salts Cave is 1809 (Watson et al. 1969:7). Dates and names upon various signature rocks in Mammoth and Salts caves indicate that the majority of historic caving dates "from the last quarter or so of the 19th century to the first quarter of the 20th century" (Watson et al. 1969:7; see also Watson 1974:21–23). The vegetal antiquities (e.g., textile bags, cordage, sandals) that could be found within the dry caves were not preserved normally in surface or "open" sites. Hence, those items were especially sought for collecting, smuggling, and looting. As an example of smuggling, in 1874 or 1875 Louis Vial and some friends explored extensively in Salts Cave using a "new side entrance known only to themselves" (Watson et al. 1969:7). During one of those cave trips they found the "Salts Cave Mummy," nicknamed incorrectly "Little Alice" (Robbins 1971, 1974; K. Tankersley et al. 1994; Watson et al. 1969:7). More recent examinations by the late Louise Robbins (1971:200–206) identified the sex and age of this individual to be those of a 9-year-old male.

During the 1890s, men such as F. W. Putnam of the Peabody Museum, as well as local Kentuckians such as Colonel Bennett Young, T. F. Hazen, and W. D. Cutliff, made extensive collections and/or purchased prehistoric material from Salts and Mammoth caves. Young (1910:300, 305) stated:

> In 1893 Mr. Theodore F. Hazen . . . opened a new entrance into Salts Cave . . . [and] obtained many interesting relics . . . about the present entrance [Salts Sink], numerous spalls, flakes of flint, pestles, axes, awls, and other implements have been found . . .

Young went on to describe many artifacts taken from within Salts and Mammoth caves, such as cords of bark, hemp, cattail leaves, and grass; basketwork; half-burned cane torches; corn cobs (probably modern); an aboriginal ladder; wooden digging implements; cups, dishes, bowls, and water bottles made from gourds and squash rinds; tobacco leaves and seed pods (also probably modern); and many chert implements. The large collection of antiquities Young acquired was sold to the Museum of the American Indian, Heye Foundation, New York (Schwartz 1958e; Watson 1974:167). Later, John M. Nelson, who was a cave guide from 1894 to 1907, extensively collected antiquities both from the caves and from surrounding surface sites (Carey 1942; Schwartz 1958f:3; Watson et al. 1969; Watson 1974). With the exception of the John M. Nelson collection, the other large private collections were either given or sold to the American Museum of Natural History, the Smithsonian Institution, or the Peabody Museum of Archaeology and Ethnology. It was the Mammoth Cave Estates collection, donated to the American Museum of Natural History in 1913, that prompted Nels C. Nelson (no relation to John M. Nelson) to engage in the "only scientific archaeological investigations" (Schwartz 1958d) of the Mammoth Cave area up to that time and usher in the Classificatory Period of archaeological work (Schwartz 1967; Willey and Sabloff 1993).

The Speculative Period focused initially upon discovery, with only meager attempts to offer explanations of derivation of the discovered sites. Once they were discovered and made known, the sites were vandalized and exploited for private purposes. Whether pots, "arrowheads," or "mummies," the market for trafficking in North American antiquities had begun. But it was from the seeds of site destruction that the first museum acquisitions were made, ushering in professional archaeological work of the Classificatory Period.

The Classificatory Period: 1916–1960

Nels C. Nelson worked in Mammoth Cave National Park during May and November 1916 as an archaeological representative of the American Museum of Natural History. His 1917 report described the materials found during his surface and cave reconnaissances and excavations in the Mammoth Cave area. Specifically, Nelson described and compared his surface finds from the Mammoth Cave and Eaton Valley fields to similar bifacial chipped stone materials then being found in the French Paleolithic (Nelson 1917:16–19, 1923). In total, Nelson examined, through excavation and/or other study, six of nine cave sites, six of seven open-surface sites, and one of four rockshelters (Nelson 1917:11).The latter number refers to the category of site types he reported for the Mammoth Cave area. Douglas W. Schwartz (1958d:1–2) stated that Nelson's main contribution was to "scientifically document the presence in the caves of some classes of material previously only reported by amateurs." Nelson also drew substantial conclusions from his materials, despite the lack of published reports concerning antiquities of the area and the role of plant domestication (he found large quantities of charred sunflower seeds in his Mammoth Cave vestibule excavations) in the central Kentucky region. He concluded that the Flint-Mammoth Cave system had an economic importance to the Native Americans, e.g., the quarrying of flint (e.g., from Flint Alley in Mammoth Cave, which has since been questioned [Munson et al. 1989; Prentice 1993]); Nelson was not aware that the Native Americans also exploited the caves for minerals (e.g., mirabilite, gypsum, satin spar, and selenite; see Munson et al. 1989; K. Tankersley 1996).

Nelson's archaeological excavations inside the vestibule of Mammoth Cave is his major work in the Mammoth Cave area. Although this excavation was exploratory, it was extremely extensive and thorough. Nelson sank a series of 10 test trenches that revealed midden in two places. One was near the west wall of the entrance; the other, some 40 feet from the first, extended 50 feet back over the entire entrance area. Although Nelson's notes are at times ambiguous, he demonstrated a strong concern for the temporal and spatial location of artifacts excavated (personal observation in April 1975 of Nelson's catalog record on file with the American Museum of Natural History, New York).

Nelson excavated almost all of the vestibule entrance, but the number of artifacts found was few. Douglas W. Schwartz (1958d) explained that this was probably the result of extensive looting that had occurred earlier throughout the 19th century. It also may be the result of Nelson's recovery methods (no screens were used) and/or extensive subsurface alterations resulting from cave commercialization or previous saltpeter mining operations during the War of 1812 (Meloy 1968). Any of these reasons may explain the paucity of artifacts recovered from the Mammoth Cave vestibule. Nelson did find and recognize evidence of prehistoric diet in the form of animal bone, sunflower seeds, and freshwater molluscs (Nelson 1917; Watson 1974:212). He also found prehistoric tools such as bone awls, bone flakers, antler points, tubes, stone projectile points, scrapers, ground stone implements, and items for personal adornment. Most important, Nelson (1917:69) concluded that two different cultures could be distinguished within his vestibule excavations. The lower or more "primitive" group was identified by Nelson as what archeologists would define 2 decades later (e.g., Ritchie 1933) as the Archaic culture (Schwartz 1960a:133).

Only one other reference to Mammoth Cave area prehistory appeared in print during the first 2 decades of the 20th century. This was a fleeting mention of a series of rockshelter sites near what is now the western boundary of Mammoth Cave National Park. The reference was made by C. B. Moore who visited the Indian Hill rockshelter complex in 1915 (Moore 1916). Fortunately, shallow water conditions on Green River forced Moore to terminate his plunderous Green River expedition near Indian Hill as his boat, *The Gopher*, was too large to continue the journey upstream. In 1935, a newly discovered desiccated burial within Mammoth Cave, known to the cave guides as "Lost John," brought additional archaeological publicity to the area (Pond 1935, 1937). Alonzo Pond and George Neumann's analysis of Lost John (Neumann 1938) constituted the only professional archaeological inquiry in the Mammoth Cave area between N. C. Nelson's 1916 work and the formation of Mammoth Cave National Park (MCNP) in 1940 although several additional references to caves and rockshelter sites in and around the present boundary of the park appeared in print intermittently (e.g., Fowke 1922; Funkhouser and Webb 1932). With the final acquisition of lands by the federal government on 25 Apr 1940, it became a federal offense to remove materials from cave interiors within MCNP.

During the formation of MCNP, the Mammoth Cave National Park Association purchased, from John M. Nelson, a collection of prehistoric, historic, and geological specimens that were subsequently donated to MCNP on 15 Jan 1942 (Carey 1942:1). Henry A. Carey, then of the Archaeology Department at the University of Kentucky, was placed in charge of cataloging the park's new acquisitions. He was assisted by a new NPS employee, Jesse D. Jennings (Carey 1942). Unfortunately, the majority of the 25,000 specimens in the John M. Nelson collection was without provenience. Items in the collection had been bought from the local area with no note made as to the exact collecting location. Furthermore, Nelson kept only "mental notes" for his more unusual specimens. From the John M. Nelson collection, Henry Carey concluded (1) that the MCNP area was utilized for an extensive period of time by aboriginal peoples; (2) that a typological sequence could be worked out for the area by using the collection but extreme caution should be used in drawing definitive conclusions due to the lack of controlled locational data; and (3) that scientific archaeological excavations inside the caves and at selected surface sites should be started immediately. Unfortunately, due to the start of World War II, the Mammoth Cave collections heralded for study by Carey were not examined again until 1957 when Douglas W. Schwartz, from the University of Kentucky, examined the John M. Nelson materials and attempted to relocate some of the surface sites from which John Nelson had made his collections (Schwartz 1958f). Schwartz also brought systematization to the study of Native American sites in MCNP and visited several major museums in the East to study collections acquired from the Mammoth Cave area at the turn of the century (Schwartz 1958a–h). These activities culminated in a series of valuable descriptive reports (Schwartz 1958a–h) and other interpretive and popular accounts about the archaeology of the area (Schwartz 1960a; 1965).

The Classificatory Period brought a logical, scientific inquiry to the archaeology of the Mammoth Cave area. With the first work of Nelson in 1916, to the discovery of a desiccated individual (Lost John) in 1935, to the systematic reporting of archaeological sites above ground and below by Douglas Schwartz during the late 1950s/early 1960s, the archaeology of the Mammoth Cave area yielded, ever so slowly, evidence of very significant information about prehistoric cultural adaptations and cultural processes. These later studies served as the foundation for investigations by Patty Jo Watson, the Cave Research Foundation, the National Park Service, and the Illinois State Museum (Watson et al. 1969) during the next period of archaeological development.

The Explanatory/Interdisciplinary Period: 1960 to the Present

In 1942, Henry Carey emphasized the need for further surface investigations and excavations in MCNP, but little was accomplished until the recent research efforts by Patty Jo Watson and her associates (Brown 1977; Carstens 1974, 1975, 1976 1980; Carstens and Watson 1996; Marquardt 1972a, 1972b, 1974; Marquardt and Watson 1976, 1983; Robbins 1971; Wagner 1976; Watson et al. 1969; Watson 1974). Whether you call it explanatory archaeology, processual archaeology, or even post-processual archaeology, the post-1960 era of *interdisciplinary* archaeological research in the central Kentucky karst began to answer many questions about the area's prehistory and the avenues of cultural change and adaptation through time and space.

Watson's archaeological work in MCNP began in 1962 when, in conjunction with the Cave Research Foundation, the Illinois State Museum, and MCNP, she initiated an archaeological reconnaissance of the large caves within the Flint Mammoth Cave system (Carstens and Watson 1996; Watson et al. 1969:v). Watson's initial work was carried out primarily in Salts Cave, but later research expanded into other caves (e.g., Mammoth, Lee, and Bluff), and to archaeological surface reconnaissance (Carstens 1974, 1980). Watson's reason for studying the cultural materials from within the caves was that data derived from those materials were highly relevant to the discovery of dietary practices during the early agricultural Late Archaic-Early Woodland period. Watson's research was expanded in April 1969 to include, "excavation in Salts Cave Vestibule, a search for and testing of possible surface sites near Salts Sink, and recording of prehistoric remains in other caves within the Park" (Watson et al. 1969:v). Between 1973 and 1980, Watson and her colleagues initiated comparative studies at caves outside the park (e.g., Wyandotte Cave, Indiana, and Wolf River or Jaguar Cave, Tennessee) (Crothers 1986; Munson and Munson 1990; Robbins et al. 1981; K. Tankersley et al. 1994; S. Tankersley 1993). She also obtained a more complete radiocarbon sequence from Salts and Mammoth caves, excavated and floated a stratigraphic column from Salts Cave vestibule; obtained pollen and parasitological analyses from human paleofecal specimens found within the cave, and took pollen core samples from nearby sinkhole ponds.

Aided in her research by scientists from many different fields of study, Watson was able to approach the archaeological problems of the MCNP in a scientifically integrated manner, a methodological approach she had learned as a University of Chicago graduate participating in Robert Braidwood's interdisciplinary studies of agricultural origins in the Near East. This approach led to some answers and to many new questions, particularly with respect to environmental changes and their possible effects on the prehistoric inhabitants of the study area. Watson and her colleagues (e.g., Munson et al. 1989; K. Tankersley 1996; K. Tankersley et al. 1985) documented that prehistoric people using the cave were mining the cave for minerals (e.g., mirabilite, gypsum, selenite, and satin spar) and were simply exploring the cave system. She noted similar patterns of cultural activities in portions of other caves located inside (Lee and Bluff) and outside the park boundaries (e.g.,Wyandotte Cave in Indiana, and Big Bone and Jaguar caves in Tennessee; Crothers 1986; Munson and Munson 1990; Watson 1986:109–116).Although Lee, Bluff, Wyandotte, and Jaguar caves are not comparable in size to either Salts or Mammoth Cave, the data collected by Watson and her colleagues clearly indicate that cave mining and exploration were widespread activities in this karstic region that probably began during the Late Archaic (Crothers et al. n.d.; Munson et al. 1989; Watson 1986; Watson 1974:221–232; Watson and Kennedy 1991). The 50+ radiocarbon dates now available for the Mammoth Cave archaeological project clearly demonstrate the widespread prehistoric use of caves over a very important and similar time horizon (Kennedy 1990, 1996): that of early agriculture in the Late Archaic-Early Woodland period (ca. 4000 to 2000 B.P.).

Watson's research between 1962 and 1980 in the Mammoth Cave region is unique for two reasons: (1) it is the first time such scientifically integrated archaeological deep-cave research has been attempted in the eastern U.S.; and (2) it provides an aspect of prehistoric culture process that was extremely important (i.e., the domestication of native plants, evidence for which was not then being found in "open" surface sites in the eastern U.S.). Watson's research continues in the Mammoth Cave region.

As a part of the Watson research team between 1973 and 1975, my job was to document the culture history evident in a sample of 83 surface sites in and around MCNP, examining the techno-economies of several of those sites diachronically and presenting a cultural historical context within which the surface dwellers of the central Kentucky karst explored and exploited the large caves (Carstens 1980).

Between 1977 and 1987, MCNP witnessed only intermittent archaeological research on the park's surface archaeology. Most of the work accomplished included small, unrelated cultural resource management surveys (e.g., Beditz 1979, 1981; Carstens 1977, 1978). Between 1981 and 1989, few archaeological projects were conducted on the surface of MCNP. Exceptions are the work of Philip J. DiBlasi, who investigated the 1920s homestead of Floyd Collins (DiBlasi 1987a), a famous local cave explorer, and George Crothers, who documented material left in Sand Cave where Collins died in 1925 (Crothers 1981, 1983). DiBlasi (1987b, 1996), working with the Cave Research Foundation, also found in Salts Cave a series of prehistoric pictographs and glyphs previously undocumented. Other studies concerning the human use of the cave system, and of the people who were using the cave, focused on determining the exact nature of prehistoric mineral procurement (K. Tankersley 1996), forensic examinations of the historic findspots of mummies (K. Tankersley et al. 1994; S. Tankersley 1993), and a new and exciting search for pathogenic microorganisms in prehistoric and historic human feces and bodily fluids (Ruppert 1994; S. Tankersley 1993).

The most systematic undertaking to inventory a representative sample of the park for both historic and prehistoric cultural resources was directed by NPS archeologist Guy Prentice (1993). Although much of Prentice's prehistory is a summary of Nelson (1917), Schwartz (1958a–g), Carstens (1980), and Watson and Carstens' (1982) site inventories, Prentice adds new prehistoric and historic sites to the overall resource inventory of the park. As a result, Prentice (1994, 1996) was able to offer a settlement synopsis of MCNP for his doctoral dissertation that includes a hypothetical seasonal round between the Big Bend shell mound area and the Mammoth Cave area.

In 1993, the Science and Resource Management Division at MCNP began a long-term cultural resource inventory of all artifacts (historic and prehistoric) within the main cave in Mammoth Cave. This project is co-sponsored by the NPS and Earthwatch; the field work for this project has been directed by Ken Tankersley, Mary Kennedy, George Crothers, Christine Hensley, and Bob Ward (Kennedy 1993; Crothers and Ward 1995). Using an

Table 1. Archaeological Research in the Area of Mammoth Cave National Park, 1824 to the Present (not an exhaustive list).

Speculative-pre-1915	Rafinesque (1824), Young (1910)
Classificatory 1916–1970	Carey (1942); Fowke (1922); Funkhouser and Webb (1932); Hanson (1960); Meloy (1968); Moore (1916); Nelson (1917, 1923); Neumann (1938); Pond (1935, 1938); Schwartz (1958a–h; 1960a, 1960b, 1965, 1967); Schwartz and Hanson (1961); Schwartz and Sloan (1958, 1960a, 1960b); Schwartz, Sloan, and Hanson (1960).
Explanatory-Interdisciplinary 1971 to the present	Beditz (1979, 1981); Carstens 1974, 1975, 1976, 1977, 1978, 1980); Carstens and Watson (1996); Crothers (1981, 1983); Crothers et al. n.d.; Crothers and Ward (1995); DiBlasi (1987a, 1987b, 1996); Duffield (1974); Hensley (1995, 1996); Kennedy (1990, 1993, 1996); Kennedy and Watson (1997); Marquardt (1974); Molnar and Ward (1974); Munson et al. (1989); Prentice (1993, 1994, 1996); Robbins (1971, 1974, 1980); Robbins et al. (1981); Ruppert (1994); Schoenwetter (1974); K. Tankersley et al. (1994); S. Tankersley (1993); Wagner (1976); Watson (1974, 1986, 1992); Watson et al. (1969); Watson and Carstens (1975, 1982); Watson and Kennedy (1993).

Electronic Distance Measurement (EDM) system, the Earthwatch team records the exact location of every artifact noted within the surveyed areas of the cave system. This makes it possible to prepare density plots of aboriginal activity within the cave system and to determine prehistoric use areas within the cave despite 200 years of historic cave use and cave disturbance to the aboriginal materials in Mammoth Cave.

In 1992, Patty Jo Watson, Mary Kennedy, Kristen Gremillion, and Kristin Sobolik began a new study in Mammoth and Salts caves.This new arena emphasized the collection of human paleofecal samples for radiocarbon dating, parasitological analysis, macro- and microethnobotanical studies, and biochemical (hormonal) analysis. These studies would allow prehistoric fecal specimens to be sexed and thereby enable a better understanding about specific individuals who explored and mined prehistoric Mammoth Cave (Watson 1992; Watson and Kennedy 1993).

In 1994, Christine Hensley and Tom Sussenbach, while working for the NPS in MCNP, conducted excavations at the stairway rockshelter (Hensley 1995, 1996). The three radiocarbon samples from Hensley's excavations of Feature 1 consistently place the site's occupation in the Early Woodland period, ca. 2170 to 2570 B.P., a date range quite comparable to the majority of aboriginal use of Mammoth and Salts caves (Hensley 1995:24, Table 1; Kennedy 1990, 1996). Further, Paul Gardner identified more than 5000 seeds of domestic, semi-domestic, and wild chenopodium from the rockshelter occupation floor (Hensley 1995, 1996). Similar contractual archaeological studies continue today through the supervision of Bob Ward, cultural resource specialist at MCNP and the assistance of Darlene Appelgate, archaeologist at Western Kentucky University (Appelgate pers. comm. 1 July 2000).

Analytically, the Explanatory/Interdisciplinary (post-1960) era of archaeological research has answered many questions about the Native Americans who explored and exploited the environment and resources above and below ground in the central Kentucky karst. Initial studies by Watson and her colleagues in the early 1960s through 1980s focused upon time-space and environmental reconstruction sequences, then turned to more processual issues while unraveling the prehistory of the Mammoth Cave area. That work inspired other archeologists in Tennessee and Indiana to test several of Watson's observations and conclusions about the prehistory of Mammoth Cave specifically, and prehistoric cultural processes in general, finding that prehistoric aboriginal mining and exploration was a widespread cultural phenomenon; it was not limited solely to MCNP or only to the Late Archaic-Early Woodland transition (e.g., Faulkner 1986). Furthermore, not only had Watson and her associates confirmed and expanded N. C. Nelson's initial observations about the importance of plant cultivation in the Mammoth Cave area, but they also went far beyond, examining human paleofeces for parasites and micro-organisms and determining whether prehistoric caving activities were carried out by both sexes, thereby helping to engender, and more accurately describe, Mammoth Cave prehistory.

DISCUSSION

The history of archaeology in the Mammoth Cave area closely parallels the growth and development of archaeological trends in North America. From the Speculative to the Classificatory to the Explanatory and Interdisciplinary periods, archaeological inquiry in the central Kentucky karst has demonstrated that the uncommon preservation characteristics of the cave environment provides unique insight into human behavior (prehistoric and historic) that may be more accessible than from open "surface" sites. Table 1 also reflects that, along with an increase in the intensity of cave archaeological investigation, a greater sophistication began once interdisciplinary research was initiated at the park (post-1960). That work was initiated by Patty Jo Watson and her associates and colleagues.

Early turn-of-the-century interests in cave archaeology, primarily atheoretical, prompted work at surface sites in the Mammoth Cave area and led to speculation about the origins of prehistoric cultural materials, sometimes comparing them to the better-understood European record (e.g., Nelson 1917; Young 1910).Assessing significance of and attempting to order archaeological sites from within the park area, both above ground and below, and assessing Mammoth Cave collections held outside the park, were the foci of the Classificatory Period between 1916 and 1970, culminating in the summaries of Douglas W. Schwartz (1958a–h, 1960a, 1960b, 1965). More recent work by Watson and her colleagues brought a theoretical and interdisciplinary framework to the archaeology of the park often reflecting various themes prominent in the "New Archaeology." Within the last decade cave art studies (DiBlasi 1996) have added a cognitive, or post-processualist research slant to the efforts begun by Watson's group. However, additional research is still needed in the Mammoth Cave area, above ground and below. Only the tip of the proverbial iceberg at Mammoth Cave has been studied, whereas artifacts from surface sites and from within the caves continue to be damaged or stolen in spite of the security efforts of the NPS. New insights and new energies are needed today to carry on the fascinating study of the aboriginal and Euro-American people who explored and exploited the Kentucky underworld.

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sing Composts as Growth Media in Container Production of Tomatoes

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ABSTRACT

During the 1996 and 1997 growing seasons, soil (S), brush composts (B), leaf composts (L), N-Viro Soil (N), and 50:50 mixtures of these materials (S:B, S:L, S:N, B:L, B:N, L:N) by volume were compared for their effects on seasonal distribution and total production for four tomato (*Lycopersicon esculentum*) cultivars. Each growth medium was replicated in four containers (58 cm diameter, 38 cm depth; ca. 64 liters capacity). The cultivars were 'Celebrity', 'Patio', 'Large Red Cherry', and 'Small Red Cherry.' Results were based upon weekly production of vine-ripened fruits by each plant from mid-July to mid-October. The growth media were similar in their effects on seasonal distribution and total fruit production. All growth media/cultivar combinations gave continuous tomato production throughout the growing season. Cultivar differences were exhibited in both plant and fruit characteristics, permitting the container gardener to practice individual preferences. Overall, the results support the practice of composting waste products for use in container gardening.

INTRODUCTION

Sustainability of society is enhanced when recurring waste products are effectively substituted for diminishing natural resources. The sustainable dimension of food production is receiving public attention and tangible government support (Hudson and Harsch 1991).

Composting is an age-old process for converting organic residues into forms that are more aesthetically acceptable and more available for plant utilization. Composting is receiving renewed support as a means of waste disposal because the process reduces the volume of yard waste by a factor of five times or more and results in a product suitable for garden or landscape utilization (Fine 1989). In 1992, 85% of the 4.6 million tons of solid waste produced in Kentucky were disposed in landfills. The Environmental Protection Agency set a goal to reduce municipal solid waste going into landfills by 25% (Environmental Almanac 1994). Since yard waste accounts for ca. 18% of municipal solid waste, composting is critical to efficient waste management.

Organic gardening is based upon the substitution of organic sources for inorganic sources of nitrogen. Recent increases in demand for organically grown food have expanded markets for composted organic matter. Organic gardening varies in scale from individual plant containers to full-sized family gardens (Lindgren et al. 1990).

Urbanites have become increasingly involved in gardening during recent years. They utilize small plots or containers to provide ongoing supplies of fresh fruits and vegetable. In addition, gardening serves as a hobby that for many people is a source of pleasure, pride, and satisfaction. These benefits are not dependent on garden size (Bartholomew 1981).

Tomato (*Lycopersicon esculentum*) is the crop of choice by most urbanite gardeners. Research has shown that tomato yields from litter-enriched plots matured earlier and were larger than those grown in commercially fertilized plots (Brown et al. 1995).

The present study was part of an ongoing program sponsored by the Department of Agriculture, Western Kentucky University (WKU), to convert local municipal waste into forms usable in gardening and landscaping. Our objectives were to compare different waste composts for their effects on total and seasonal distribution of production of diverse tomato cultivars grown in containers.

MATERIALS AND PROCEDURES

Composts

Three locally available waste products were evaluated. Brush- and leaf-composts were produced from Bowling Green yard waste collected in 1994. In a tree inventory of Bowling Green, Martin (1994) identified a variety of common deciduous trees including ash, elm,

Table 1. Nutritive value of composts used in container production of tomatoes.

Compost	% N	% P	% K	Carbon: Nitrogen Ratios
Brush (B)	0.99	0.08	0.48	30:1
Leaf (L)	0.88	0.04	0.42	33:1
N-Viro soil (N)	0.96	0.36	0.67	16:1

dogwood, maple, mulberry, oak, redbud, and willow as well as numerous ornamental trees. The sewage compost, known by the trade name N-Viro Soil (Kovacik 1988), is prepared by mixing treated sewage sludge with cement kiln dust according to approved procedures. The resulting moist mixture is aerated and composted on an environmentally approved site. The Pembroke silt loam soil, obtained from the WKU farm, tested medium to high in both phosphorus and potassium.

Containers

The study was based on container-culture to permit greater experimental control of the compost mixtures and to extend the applicability of the results to container gardening. Forty plastic barrel sections (58 cm diameter, 38 cm depth) were located in an unshaded area. Containers were embedded in the soil to reduce drying and were punctured in the bottom to permit drainage. They were spaced 1.5 m apart in 5 rows and 8 columns. Each container received ca. 64 liters of compost mixture.

Growth Media

Soil and the three composts were used make 10 growth media; four consisted 100% each of soil (S), brush compost (B), leaf compost (L), and N-Viro Soil (N), and six consisted of 50:50 combinations by volume of the soil compost materials (S:B, S:L, S:N, B:L, B:N, L:N). All growth media were supplemented prior to transplanting with fertilizer at the rate of 56.0, 24.5, and 46.5 kg/ha-t of N, P, K, respectively. No additional fertilizer was applied.

Cultivars

Four diverse tomato cultivars—'Celebrity', 'Patio', 'Large Red Cherry', and 'Small Red Cherry'—were studied. 'Celebrity' is an indeterminate garden type that produces large plants and large fruits. 'Patio' exhibits a compact, determinate growth habit and is more suitable for urban or "patio" production. 'Large Red Cherry' and 'Small Red Cherry' are characterized by indeterminate growth habit and smaller fruits.

Production

One plant, ca. 15 cm tall, was transplanted in mid-May to each container. Vine-ripened fruits were harvested twice a week beginning in mid-July and continuing to mid-October. Fruits from each plant were counted and weighed. Data from the two harvests per week were combined and reported as production on a weekly basis. After the last regular harvest,

Table 2. Season production of tomato fruits per plant in 1996, Bowling Green, KY.

Growth Media[1]	Cultivar[2] C	P	Mean[3]	C	P	Mean[3]
	Number			Weight (kg)		
S	100	52	76	13.3	4.97	9.14
B	64	68	66	9.55	6.96	8.26
L	92	58	75	15.34	3.6	9.47
N	87	52	70	12.07	5.4	8.74
S-B	87	65	76	13.41	5.92	9.66
S-L	99	66	82	15.64	7.35	11.5
S-N	74	68	71	10.3	6.52	8.41
B-L	120	57	88	17.25	5.51	11.38
B-N	136	64	100	17.25	5.94	11.6
L-N	98	83	90	13.29	6.79	10.04
Mean[3]	95.7a	63.3b	79.4	13.74a	5.89b	9.82

[1] S = soil, B = brush compost, L = leaf compost, N = N-Viro Soil.

[2] C = 'Celebrity', P = 'Patio'.

[3] Growth mixture means were not significantly different ($P > 0.05$); Cultivar fruit number and fruit weight means followed by the same letters are not significantly different ($P > 0.05$).

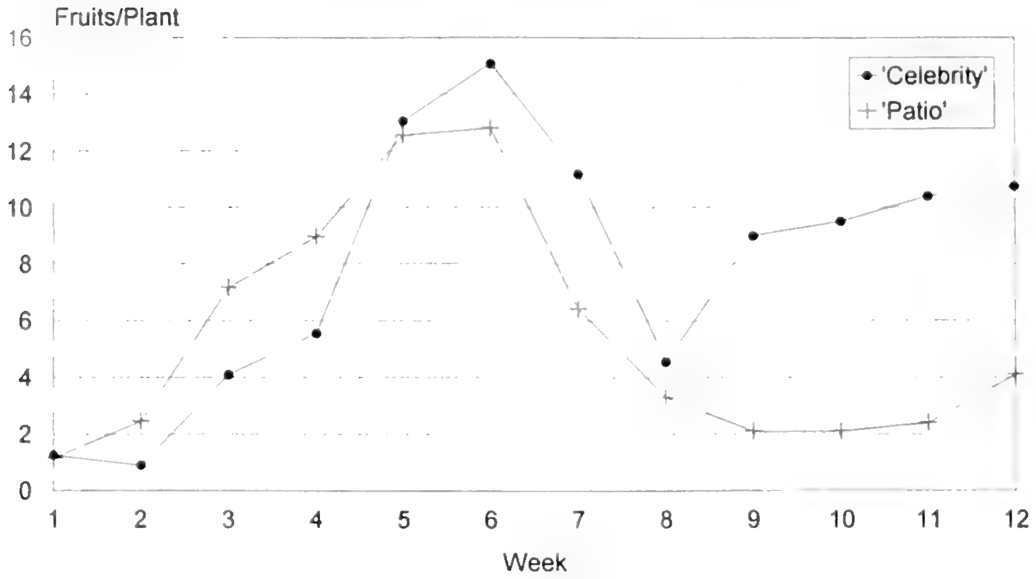

Figure 1. Season distribution of number of fruits/plant for 'Celebrity' and 'Patio' tomatoes in 1996, Bowling Green, Kentucky.

remaining green fruits were counted and weighed.

Supplemental water was applied usually once or twice per week to prevent plant wilting. Support stakes placed in the periphery of the containers were connected with loose-fitting twine to provide plant support. Plants were permitted to spread without any restrictive pruning.

Design and Analysis

The 10 growth media were replicated four times in a randomized complete block design (Steel and Torrie 1980). In 1996, 'Celebrity' and 'Patio' were studied, resulting in two replications of each cultivar per growth medium. In 1997, the addition of 'Large Red Cherry' and 'Small Red Cherry' resulted in one replication for each cultivar per growth medium. Data analyses were directed toward both seasonal distribution and total production of number and weight of fruits.

RESULTS

Compost Analysis

Nutritive values for the brush- and leaf-composts were about equal for N (ca. 1%), P (trace), and K (0.45%), whereas N-Viro Soil had a similar level of N (ca. 1%) but higher levels of P (0.56%) and K (0.67%) (Table 1). Variance among the C:N ratios was the most important difference in nutritive value of the

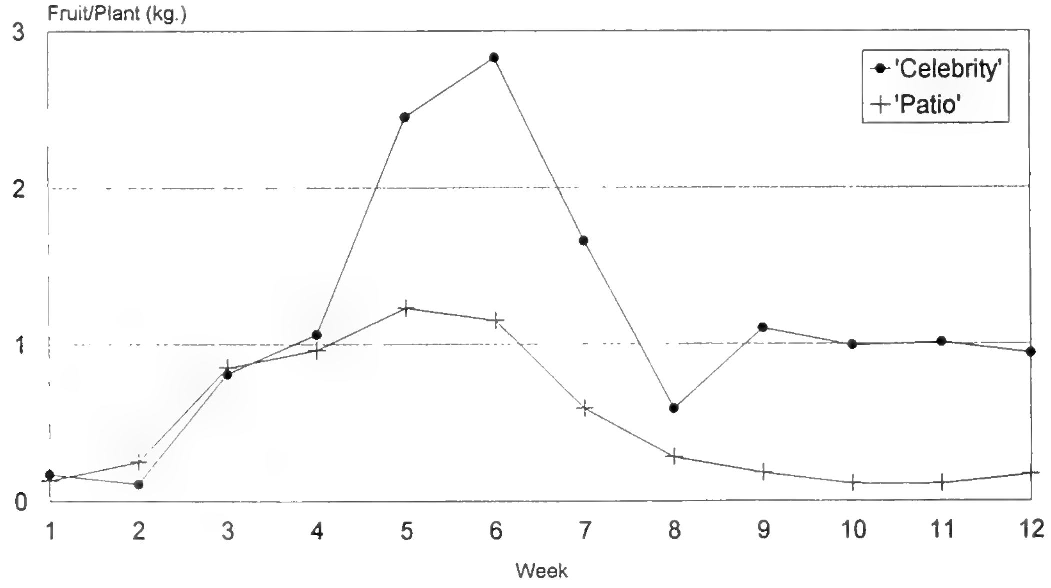

Figure 2. Season distribution of weight of fruits/plant for 'Celebrity' and 'Patio' tomatoes in 1996, Bowling Green, Kentucky.

Table 3. Season production of tomato fruits per plant in 1997, Bowling Green, KY.

Growth Mixture[1]	Cultivar[2] C	P	LRC	SRC	Mean[3]	C	P	LRC	SRC	Mean
	Number					Weight (kg)				
S	60	51	525	940	394	5.15	2.42	8.18	4.01	4.94
B	51	76	67	1082	319	7.19	3.21	1.26	5.2	4.22
L	91	34	383	710	304	9.68	4.44	5.94	4	6.02
N	73	34	408	980	374	10.17	3.84	6.34	4.54	6.22
S-B	45	60	362	765	308	7.56	6.08	6.06	4.13	5.96
S-L	80	28	270	786	291	9.31	1.91	4.19	3.92	4.83
S-N	47	41	320	1017	356	5.2	3.5	5.2	4.92	4.7
B-L	92	45	344	794	319	11.68	3.69	6.57	4.03	6.49
B-N	39	40	457	1077	403	4.69	3.76	7.79	5.86	5.52
L-N	57	32	353	899	335	8.91	3.75	5.71	3.88	5.56
Mean[3]	64c	44c	349b	905a	340	7.95a	3.66b	5.72ab	4.45b	5.45

[1] S = Soil, B = Brush Compost, L = Leaf Compost, N = N-Viro Soil.

[2] C = 'Celebrity', P = 'Patio', LRC = 'Large Red Cherry', SRC = 'Small Red Cherry'.

[3] Growth mixture means were not significantly different ($P > 0.05$); Cultivar fruit number and fruit weight means followed by the same letters are not significantly different ($P > 0.05$).

composts. Ratios of 30:1, as exhibited in the brush- and leaf-composts, immobilize available N and result in N starvation of the plants. The C:N ratio of 16:1 for the N-Viro Soil should not create N deficiency in plant growth. The recommended level of fertilizer for tomato production was applied to all growth mixture to compensate for nutrient differences.

1996 Season Production

Number and weight of fruits per plant are given in Table 2. 'Celebrity' plants produced significantly more fruits (ca. 96) than did 'Patio' plants (ca. 63). Average fruit weight per plant was significantly greater for 'Celebrity' (13.74 kg) than for 'Patio' (5.89 kg). Thus, 'Celebrity' plants produced significantly more and heavier fruits than did 'Patio' plants during 1996. Although there was variability among the number and weight of fruits produced on the different growth media, yield differences associated with growth media were not significant. Analyses comparing groups of means, i.e., those mixtures including soil vs. those that did not, failed to detect any significant differences. Also, comparisons of growth media means at different harvest dates during the season failed to reveal any consistent differences.

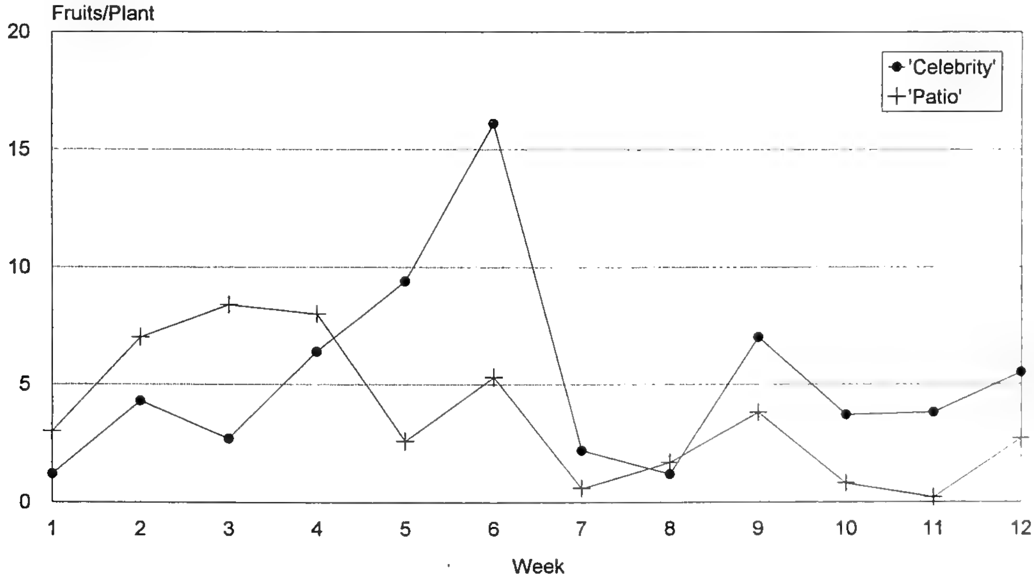

Figure 3. Season distribution of number of fruits/plant for 'Celebrity' and 'Patio' tomatoes in 1997, Bowling Green, Kentucky.

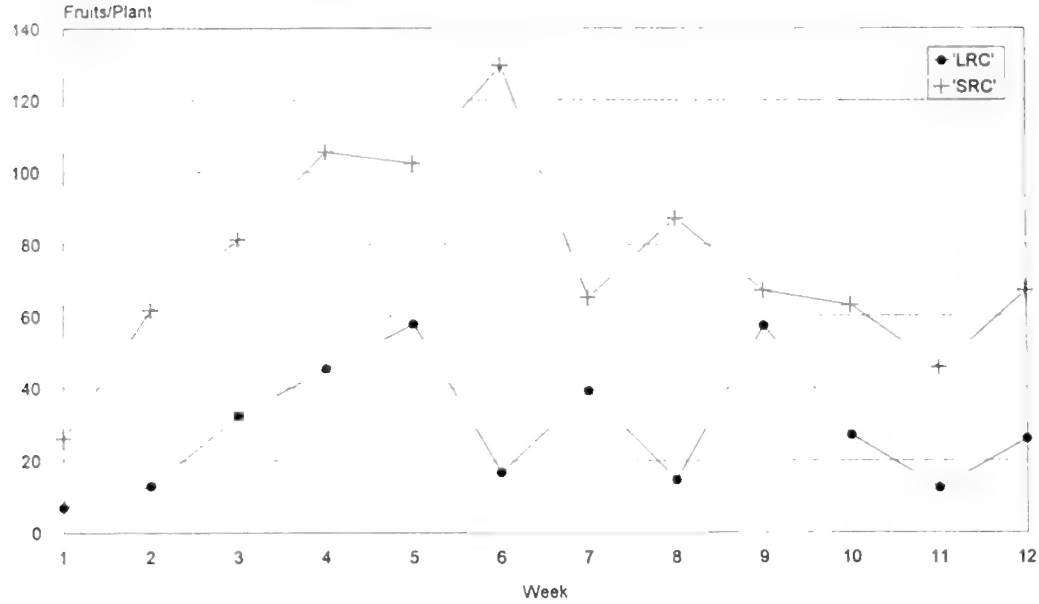

Figure 4. Season distribution of numbers of fruits/plant for 'Large Red Cherry' (LRC) and 'Small Red Cherry' (SMC) tomatoes in 1997, Bowling Green, Kentucky.

Since the growth media means did not differ significantly, yields were combined for each cultivar in determining season distributions (Figures 1, 2). Fruit ripening began in mid-July and continued until frost occurred in mid-October. Peak production for both numbers and weights of fruits occurred in late August and continued into early September. 'Celebrity' produced more and heavier fruits per plant than did 'Patio' during the second half of the season.

1997 Season Production

Number and weight of fruits per plant for each of the four cultivars are presented in Table 3. Both the number and weight of fruits per plants of 'Celebrity' and 'Patio' were lower in 1997 than in 1996. For number of fruits per plant, 'Small Red Cherry' was highest (905), 'Large Red Cherry' was intermediate (349), and 'Celebrity' and 'Patio' were lowest (64 and 44, respectively). Growth mixtures had no significant effect on number of fruits. For weight of fruits per plant. 'Celebrity' was highest (7.95 kg), 'Large Red Cherry' was intermediate (5.72 kg), and 'Patio' and 'Small Red Cherry' were lowest (3.66 and 4.45 kg, respectively). Differences among number or weight of fruits were not influenced significantly by growth mixtures when such comparisons were

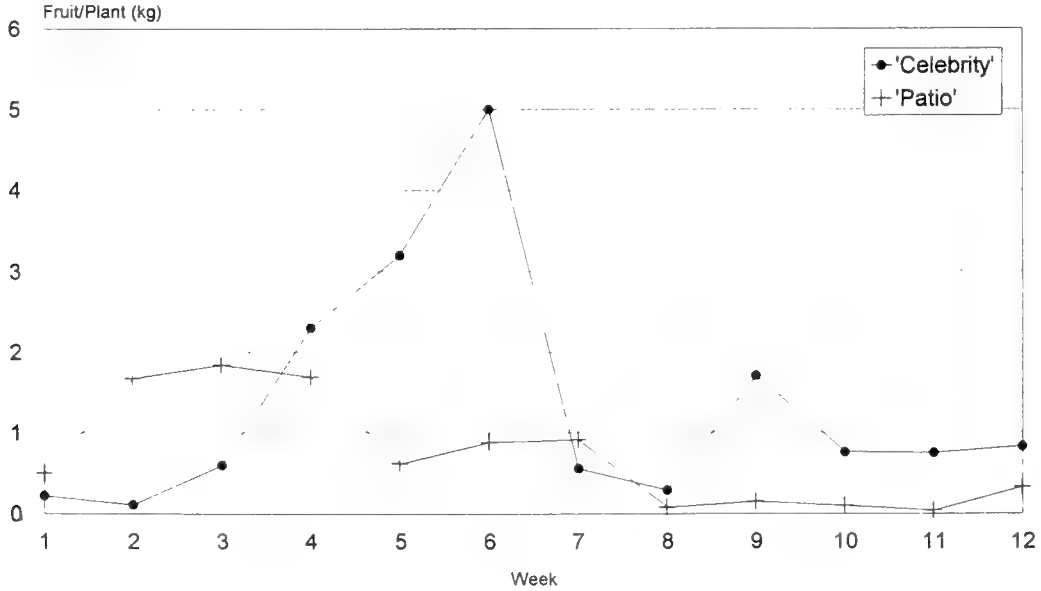

Figure 5. Season distribution of weight of fruits/plant for 'Celebrity' and 'Patio' tomatoes in 1997, Bowling Green, Kentucky.

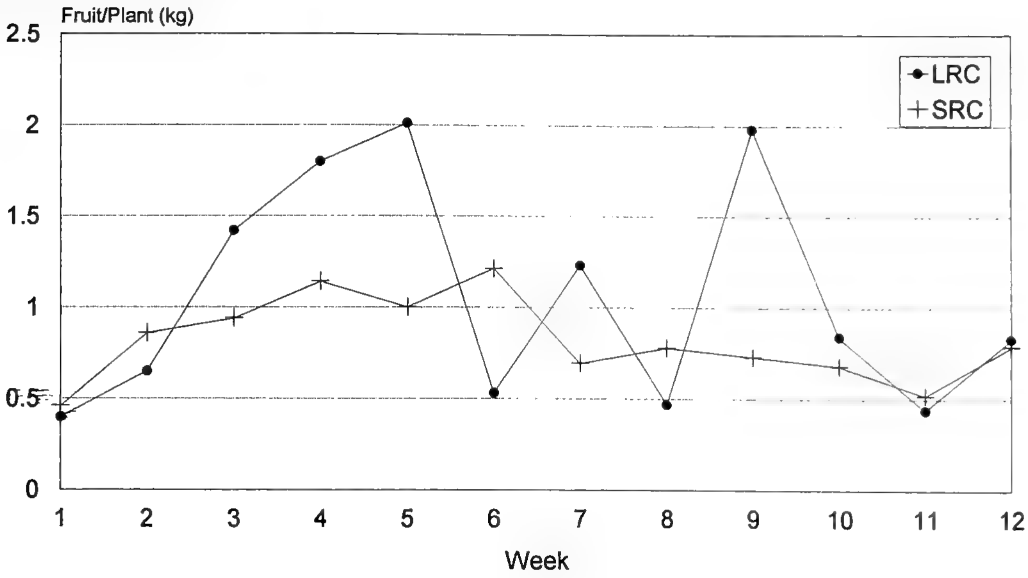

Figure 6. Season distribution of weight of fruits/plant for 'Large Red Cherry' (LRC) and 'Small Red Cherry' (SMC) tomatoes in 1997, Bowling Green, Kentucky.

based upon either total season or individual harvest period yields.

Growth mixture yields were combined for each cultivar in determining season distributions (Figures 3–6). Fruit ripening continued from mid-July throughout mid-October. For 'Celebrity' and 'Patio' the 1997 season distributions of both number and weight of fruits per plant were similar to those in 1996 with the exceptions that 'Patio' production peaked earlier in 1997 than in 1996. 'Large Red Cherry' and 'Small Red Cherry' produced an abundance of fruits throughout 1997. Peak production occurred at week 6 (end of August) for 'Small Red Cherry', but no single period of maximum production was exhibited by 'Large Red Cherry.' For weight of fruits per plant, yields were rather consistent for 'Small Red Cherry' throughout the season. whereas weight of fruits per plant decreased during early September for 'Large Red Cherry.'

End of Season Production

Following the first frost each year the unripened fruits on each plant were counted and weighed. In 1996, 'Celebrity' and 'Patio' averaged 12.8 and 22.6 fruits weighing 0.68 and 0.76 kg per plant, respectively. In 1997, 'Celebrity', 'Patio', 'Large Red Cherry', and 'Small Red Cherry' averaged 13.4, 23.7, 60.8, and 185.6 fruits weighing 0.72, 0.78, 0.48, and 0.51 kg per plant, respectively.

DISCUSSION AND SUMMARY

These results indicate that composted common waste products, either alone or in mixture, are suitable for growing tomatoes in containers. Since compost materials vary in nutritive value and C : N ratios, composted growth media need to be supplemented with a complete fertilizer (N, P, K) for protection against nutrient deficiencies.

Cultivar selection is an important consideration in container production of tomatoes. Our present results indicate that cultivar characteristics such as plant shape, plant size, and fruit number and weight are consistent whether grown in an open garden or in containers. The four cultivars exhibited different qualities for container gardening. All cultivars produced throughout the season and supported unripened fruits at the time of frost, thereby providing a continuous supply of fruits. 'Celebrity' was highly productive of large fruits as desired for some purposes. However, its large, open plants could be unsightly and problematic in the urban landscape. 'Patio' was intermediate in productivity and fruit size. Its compact plant size would be desirable in a "patio" setting. 'Large Red Cherry' produced large numbers of medium-sized fruits throughout the season. Its spreading, open plant shape could be a limitation in an urban setting. 'Small Red Cherry' was a prolific producer of small fruits throughout the season. However, smallness in fruits and the vine-like plant type could limit its utility.

These preliminary results provide encouragement for using municipal waste products for beneficial purposes. The finding that the different composts alone and in mixtures were equally effective in producing tomatoes suggests that a variety of composted waste products may be used successfully in gardening.

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BOOK REVIEW

Gary E. Dillard. 1999. Common Freshwater Algae of the United States: An Illustrated Key to the Genera (Excluding the Diatoms). J. Cramer in der Gebr. Borntraeger Verlagsbuchhandlung, Berlin. 173 pages; illus. ISBN 3-443-50026-9. Price not indicated.

Professor Gary E. Dillard put together this book after many years of teaching courses on the biology of algae at Western Kentucky University. His students were required to identify genus algae from field collections. He found that students had difficulty using published keys and descriptions because of their lack of familiarity with the technical terms used in these keys to describe algal morphology. He set out to produce this "user friendly" manual, which avoids as much as possible discipline specific language. His goal has not been fully accomplished; there is still much technical jargon in the book. The beginning student is unlikely to be familiar with terms such as lorica, epicone, hypocone, dendroid colony, and others found throughout this manual. A simple glossary would have been a most useful addition. Yet, this is the first simplified key to freshwater algae to be published since Prescott's *How to Know the Freshwater Algae* (1978), which today is hard to obtain.

The book starts with a statement of purpose and a definition of "algae" as representing a heterogeneous assemblage of oxygenic photoautotrophs that lack tissue differentiation and contain chlorophyll a. Based on this definition, algae include prokaryotic groups (the cyanobacteria and chloroxybacteria) as well as a wide variety of phylogenetically unrelated eukaryotic groups. In this section the traditional and modern systems of classification are briefly mentioned. Since the purpose of the book is to act as a key to identify algae only to the generic level, Dillard did not find it necessary to place the genera into higher categories (division, classes, orders). By doing this he also avoids discussing the recent dramatic and sometimes confusing changes in algal classification. This first section of the book calls attention to the extensive bibliography for those readers interested in phylogenetic relationships among the algae or in proceeding to spe cies identification.

The next section, on algal habitats and collection methods, describes how to obtain qualitative samples with, for example, plankton nets or artificial substrates, for the purpose of conducting a survey of algal forms. There is no description of standard quantitative methods.

The rest of the book is divided into nine sections where genera are grouped by artificial characteristics such as presence of flagella. By this system phylogenetically related taxa may not cluster together. The sections are I: Charales, plant-like genera; II: unicellular flagellated genera; III: unicellular, non-flagellated genera; IV: colonial, flagellated genera; V: colonial non-flagellated genera; VI: unbranched filamentous genera; VII: branched filamentous genera; VIII: pseudoparenchymatous genera; and IX: coenocytic or sac-like genera. Within each section, the dichotomous keys to the genera are easy to follow, and each genus is illustrated with a detailed drawing. This manual excludes diatoms and many genera that occur largely in soil or aerial habitats.

Although the title of the book indicates that it deals with algae "of the United States," most genera of algae are cosmopolitan in distribution and the book can find users worldwide. There is a growing global demand for identification of freshwater algae. This demand is no longer restricted to academic circles and phycology classes. Identification of algae is a skill valued by drinking-water utilities whose operators are concerned with the presence of possible taste-, odor-, or toxin-producing species in their source water. It is also valued by environmental regulatory agencies that use algae as water quality indicators. Recently the U.S. Environmental Protection Agency (EPA) has added algae to its "Candidate Contaminant List" (CCL). This will increase the demand for the identification of algae. Like the students enrolled in the author's algae class, most people needing to identify common freshwater algae lack knowledge of the technical jargon. Many of them currently use "picture keys," particularly color charts available from the EPA that even have species names (not just genera) often associated with a picture. This commonly leads to misidentifications since the important diagnostic features are not learned when one does not follow a written key. The publication of this manual is timely. It will be useful to anyone needing to identify common freshwater algae to genus.

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Abstracts of Some Papers Presented at the 2000 Annual Meeting of the Kentu Academy of Science

AGRICULTURAL SCIENCES

Insecticides from wild tomato: phase I—breeding, trichome counts, and selection of tomato accessions. GEORGE F. ANTONIOUS, Department of Plant and Soil Science, Kentucky State University, Frankfort, KY 40601.

Among the thousands of secondary metabolites that underlie the characteristic properties of higher plants are a diverse assemblage of potentially toxic allelochemicals. Allelochemicals are those natural products that affect the growth, health, behavior, or population biology of members of other species. These compounds may impart a selective advantage to plants by inhibiting, repulsing, and even killing non-adapted organisms that may feed upon or compete with the producing plant. Production of toxic chemical compounds is one method by which trichomes (leaf-hairs) can impart resistance. In the present investigation morphological and chemical characteristics of two glandular trichomes (type IV and type VI) of six wild tomato accessions of *Lycopersicon hirsutum f. hirsutum,* four accessions of *L. hirsutum f. glabratum,* two accessions of *L. pennellii,* and density of type VI glandular trichomes of the commercial tomato *L. esculentum* cv. Fabulous, are reported. Densities of type IV and VI glandular trichomes varied among the accessions tested. Trichome counts on the leaf surface were correlated to three types of trichome exudates. Two methyl ketones (2-tridecanone and 2-dodecanone), two sesquiterpenes (zingiberene and elemine) and total glycolipids (sugar esters) in glandular trichomes have been quantified per unit leaf area. Identifying the constituents of glandular trichomes was achieved using chemical methods.

Residues of pyrethrins and piperonyl butoxide in soil, water and on potato leaves. GEORGE F. ANTONIOUS* and GAYATRI A. PATEL, Department of Plant and Soil Science, Kentucky State University, Frankfort, KY 40601; JOHN C. SNYDER, Department of Horticulture, University of Kentucky, Lexington, KY 40546.

Residues of pyrethrin-I (Py-I) and pyrethrin-II (Py-II), the major insecticidal components of the pyrethrum daisy (*Tanacetum cinerariifolium*), as well as residues of piperonyl butoxide (PBO, a pyrethrum synergist), were determined in soil and on potato foliage grown under field conditions. A pyrethrum formulation "Multi-Purpose Insecticide" containing the three active ingredients was sprayed twice at the rate of 6 lbs per acre of formulated product (5.4 and 27.2 g A.I. of pyrethrins and PBO, respectively) on potato foliage during the growing season. In soil, three management practices (yard waste compost, grass filter strips, and a no mulch treatment) were used to study the impact of surface soil characteristics on the amount of pyrethrins and PBO retained in soil. Soil samples and potato leaves were collected at different time intervals after spraying. Samples were purified and concentrated usi solid-phase extraction columns containing C_{18}-octadecy bonded silica. Residues were quantified by high-performance liquid chromatograph equipped with a UV detector. Following the first spray, the initial deposits were 0.18, 0.40 and 0.99 μg/g potato leaves for Py-I, Py-II, and PBO, respectively. Py-I and PBO residues in soil were higher in compost treatments compared to no mulch treatments.

Effects of nitrogen fertilization on monoculture and biculture cover crops in vegetable production. G. R. CLINE,* A. F. SILVERNAIL, and K. KAUL, Community Research Service, Kentucky State University, Frankfort, KY 40601.

A four year experiment examined how winter cover crops were affected by plus (+N) or minus (−N) previous inorganic nitrogen (N) fertilization of sweet corn (*Zea mays* L.) and by kill dates associated with vegetable tillage methods. Hairy vetch (*Vicia villosa* Roth) yields and nitrogen contents remained relatively constant in all years and were not affected by nitrogen treatments. In the +N treatment, yields of winter rye (*Secale cereale* L.) and a vetch/rye biculture normally exceeded vetch yields. Nitrogen contents of vetch and biculture cover crops were generally similar and were greater than those of rye. In contrast to rye, vetch and biculture cover crop nitrogen contents were similar in +N and −N treatments. Delaying cover crop kill dates by eight days for no-till vegetables increased vetch yields but did not affect vetch nitrogen contents. In the biculture treatment, vetch competed better with rye as nitrogen availability decreased. Total yields of the biculture cover crop were generally greater in the +N than in the −N treatment.

Assessment of genetic diversity within pawpaw (*Asimina triloba*) patches. SHERI B. CRABTREE,* TERA M. BONNEY, SNAKE C. JONES, and KIRK W. POMPER, Land Grant Program, Kentucky State University, Frankfort, KY 40601-2335.

The pawpaw (*Asimina triloba*) is a native tree fruit found in the southeastern and midwestern United States: it has great potential as a new high-value crop in these areas. Kentucky State University is the site of the USDA National Clonal Germplasm Repository for *Asimina* spp., and our long-term goal is to develop a sampling strategy to assess levels of genetic diversity in pawpaw across its native range. The objective of this study was to determine the level of genetic similarity among trees in pawpaw patches. Since pawpaws sucker profusely from the roots, our hypothesis is that pawpaw patches are at least partially clonal. Pawpaw leaf samples were collected from three different patches in Franklin County, Kentucky, in May 1999. DNA was extracted from the leaves, then analyzed using either the inter simple sequence repeat PCR (ISSR-PCR) or the random amplified polymorphic DNA methodology. One ISSR-PCR primer (UBC 855) yielded polymorphic markers in a subset of samples from patch #1 and a RAPD primer (OPA-11) yielded polymorphic markers in a subset of samples from patch #2. The identification of marker polymorphisms suggests that the pawpaw patches are not completely clonal. Primer screening and patch evaluation will continue.

Influence of Cry9C *Bacillus thuringiensis* transformed corn kernels on two stored product moth pests in the laboratory. JEROME R. FAULKNER,* ANTHONY M. HANLEY, BRYAN D. PRICE, and JOHN D. SEDLACEK, Land-Grant Program, Kentucky State University, Frankfort, KY 40601.

The Indian meal moth (IMM) and Angoumois grain moth (AGM) are global pests of stored grains. Growing concern regarding increasing resistance development to insecticides by insects, perceived risks associated with residues in foods, the Food Quality Protection Act of 1996, and Montreal Protocol have focused research efforts on alternative methods of pest control. Relatively recent developments in pest management of corn utilize transgenic plants (rDNA-modified) containing *Bacillus thuringiensis* (Bt) toxin genes. Bt Cry1A(b) or Cry9C delta-endotoxin is present in various tissues of transformed corn plants. It was found recently that corn kernels of some Cry1A(b) Bt isolines cause reduced IMM and AGM emergence and egg production. Some Cry9C isolines have been examined for survivorship and development of IMM. However, fecundity of IMM and all life history parameters of AGM need to be examined. Thus, the objective of this research was to quantify the effects of Cry9C transformed corn kernels on IMM and AGM life histories. Experiments were conducted at 27 ± 1°C and ≥60% RH using Starlink™ Bt corn kernels (AgrEvo), its non-Bt isoline, and topically applied Bt to the non-Bt kernels. Fifty eggs were placed in ventilated pint jars containing 170 g of cracked or whole corn for IMM and AGM, respectively. Adult emergence and fecundity were lower for both IMM and AGM in the Cry9C corn kernels and Bt treated seeds than controls. Results are consistent with those obtained for IMM and AGM reared on Cry1A(b) transformed grain.

Impact of Cry1Ab transformed corn kernels on Indian meal moth and Angoumois grain moth populations in farm storage. ANTHONY M. HANLEY,* JOHN D. SEDLACEK, BRYAN D. PRICE, and MICHAEL R. TINSLEY, Community Research Service, Kentucky State University, Frankfort, KY 40601.

Increased concern by consumers regarding chemical residues in food products, the development of resistance by stored grain insect pests to organophosphorus insecticides, the Food Quality Protection Act of 1996, and other federal regulations and international accords such as the Montreal Protocol, have generated a need to examine new control methods to assist or replace existing control management tactics of stored product insects utilizing several biopesticides. *Bacillus thuringiensis* (Bt) is available for use in stored grain. Currently, Dipel® is the only product registered for use in stored grain environments against Indian meal moth (IMM). Transgenic crops with insect resistant characteristics used against insect pests have been successful. One such example is transgenic Bt corn. This study examines the efficacy of Cry1Ab transformed Dekalb corn on Indian meal moth and Angoumois grain moth (AGM) populations in on-farm bin storage. One hundred bushels of Dekalb 679BTY (Bt+) and Dekalb 679 (Bt−) were added to16 bins located at the Kentucky State University Agricultural Research Farm in Franklin County, KY. One thousand IMM and AGM eggs were added to the bins twice to ensure infestation. Temperatures were recorded weekly and adult moths were quantified biweekly using sticky traps. Data from the sixth week of observation indicated that populations of IMM were twice as large in Bt− bins as those containing the Bt+ corn kernels. All data will be compiled at the finish of the field season and results will be discussed relative to on-farm storage capability and farmer impact.

Use of conservation tillage and cover crops for sustainable vegetable production. H. J. HRUSKA,* G. R. CLINE, A. F. SILVERNAIL, and K. KAUL, Community Research Service, Kentucky State University, Frankfort, KY 40601.

Research began in 1999 to examine sustainable production of bell peppers (*Capsicum annuum*) using conservation tillage and legume winter cover crops. Tillage treatments included conventional tillage, strip-tillage, and no-tillage, and winter covers consisted of hairy vetch (*Vicia villosa*), winter rye (*Secale cereale*), and a vetch/rye biculture. Pepper yields following the rye winter cover crop were significantly reduced if inorganic nitrogen fertilizer was not supplied. However, following vetch, yields of peppers receiving no additional nitrogen were similar to yields obtained in treatments receiving the recommended rate of inorganic nitrogen fertilizer. Thus, vetch supplied sufficient nitrogen to peppers in terms of yields. Pepper yields following the biculture cover crop were intermediate between those obtained following vetch and rye. When weeds were controlled manually, pepper yields following biculture cover crops were similar among the three tillage treatments, indicating that no-tillage and strip-tillage could be used successfully if weeds were controlled. With no-tillage, yields were reduced without weed control but the reduction was less if twice the amount of residual cover crop surface mulch was used. Without manual weed control, pepper yields obtained using strip-tillage were reduced regardless of metolachlor herbicide application. It was concluded that a vetch winter cover crop could satisfy nitrogen requirements of peppers and that effective chemical or mechanical weed control methods need to developed to grow peppers successfully using no-tillage or strip-tillage.

Pesticide movement under field conditions: an overview. CHRISTINE LEE* and GEORGE F. ANTO-

NIOUS, Community Research Service, Department of Plant and Soil Science, Kentucky State University, Frankfort, KY 40601.

Different management practices for growing vegetable crops on highly erodible land (10% slope) have been evaluated by the Water Quality Project at Kentucky State University. Studies were conducted to determine the influence of landscape features and soil amendments on pesticide movement into runoff and infiltration water. Three soil treatments on a Lowell silty loam soil (pH 6.7, 2% organic matter) were used to reduce soil erosion and surface water runoff. Pesticides infiltration into the vadose zone were monitored using pressure-vacuum lysimeters (n = 27). Twelve tipping bucket metering units were used to collect runoff. In 1998, three soil treatments were compared: black plastic (BP) mulch, living fescue mulch (tall fescue), and no-mulch treatments (NM, rototilled bare soil). In 1999, living fescue mulch 30 cm wide was planted between every cropping row (pepper intercropped with tomato each in a row) to create multiple barriers to runoff. Turf was also planted every other cropping row and both treatments were compared with NM treatments. In year 2000, yard waste compost was used as a soil amendment. Residues of pyrethrins (Py-I and Py-II) and piperonyl butoxide (PBO) were quantified in soil and runoff water following spraying of a pyrethrum formulation "Multi-Purpose Insecticide" containing Py-I, Py-II and PBO. Accordingly, the impact of the different soil mulches on the horizontal and vertical movement of clomazone, dacthal, endosulfan, and pyrethrins was measured and evaluated under field conditions.

Recent advances in thin-layer chromatography of pesticides. IESSHA MOORE,* HUMERA TAGUI, and GEORGE ANTONIOUS, Department of Plant and Soil Science, Kentucky State University, Frankfort, KY 40601.

Potential hazards to human health, food, soil, water, and wildlife may be created by residues from some long-lived pesticides that build up in the food chain and cause widespread contamination by pesticides. Thin-layer chromatography (TLC) can be used widely to detect and quantify residues of pesticides in various kind of samples such as food, drinking water, environmental matrixes (soil, groundwater and wastewater), biological materials, and to detect low concentrations of active ingredients of pesticides in their commercial formulations. The objective of this study was to separate and detect pesticides and related compounds using TLC plates. Methods for residue analysis of carbofuran, pirimiphos-methyl, pyrethrins, and piperonyl butoxide have been developed by KSU/Environmental Toxicology research group using selected mobile phases on silica gel plates. Hexane-ethyl acetate (80:20) and hexane-benzene-acetone (80:20:10) were used as mobile systems for best resolution. Orthophosphoric-tannic acid reagent in acetone was used as chromogenic spray reagent for simultaneous detection of pyrethrins and piperonyl butoxide in environmental samples. Critical factors of the TLC procedure and stepwise confirmation of positive results leading to flexibility of the metho presented.

Sustainable soil management practices and quality potato grown on erodible lands. GAYATRI A. PATEL,* GEORGE F. ANTONIOUS, and CHRISTINE LEE, Department of Plant and Soil Science, Kentucky State University, Frankfort, KY 40601; JOHN C. SNYDER, Department of Horticulture, University of Kentucky, Lexington, KY 40546.

Land productivity can decline when top soil is lost. In Kentucky, limited resource farmers often produce vegetable crops on highly erodible lands. The objectives of this study were 1) to quantify the impact of three soil management practices (SMPs) on quantity of potato produced on erodible land, 2) to evaluate the performance of pyrethrin and azadirachtin insecticides on potato tuber quality, and 3) to assess the impact of yard waste compost on the chemical composition (ascorbic acid, free sugars, and phenol contents) of potato tubers. Potatoes (*Solanum tuberosum* L. cv. Kennebec) were grown in a silty loam soil of 10% slope. Plots (n = 18) were 3.7 m wide and 22 m long, universal soil loss equation (USLE) standard plots, with metal borders of 20 cm above ground level. Two botanical insecticides, a multi-purpose insecticide (containing pyrethrin 0.2%) and Neemix 4EC (containing 0.25% azadirachtin) were sprayed twice on potato foliage during each of two growing seasons (1997 and 1999) at the recommended rates of 6 lbs and 2 gallons per acre, respectively. The SMPs were living fescue strips (FS) intercropped between every other potato row, soil mixed with yard waste compost (COM) and no mulch (NM) treatment (roto-tilled bare soil). The experimental design was a 2 × 3 × 3 factorial with main factors of two insecticides and three SMPs replicated three times. Potato rows (oriented on the contour of the slope) and the three SMPs were used as barriers to runoff. Average potato yield was lowest in NM and FS and highest in COM treatments. Yield obtained from the bottom of the plots was greater than that obtained from the top of plots. Tuber defects (rot, scab, sun green, hollow heart, necrosis, and vascular discoloration) were significantly different between the two growing seasons. The two insecticidal treatments and the three SMPs used did not have much influence on tuber defects.

The influence of fertilizer rate and application method on early growth and development of container grown pawpaw (Asimina triloba) seedlings. KIRK W. POMPER,* EDDIE B. REED, and SNAKE C. JONES, Land Grant Program, Kentucky State University, Frankfort, KY 40601-2355.

The pawpaw (*Asimina triloba*) is a native American tree fruit with potential as a new fruit crop and as an ornamental plant. Development of fertilizer rates and application methods to facilitate rapid container production of seedlings would be desirable to nurseries. A factorial greenhouse experiment was conducted with treatments that included four levels of slow release fertilizer (either 0, 3.8, [illegible]6 or 23 g of Osmocote per cubic foot) and three levels of liquid feed fertilizer (0, 250 or 500 ppm Peters 20N-20P-20K). Seeds were sown in rootrainers with Pro-[illegible] growing medium that contained the slow release fertilizer treatment levels. After seedlings reached 2–3 leaves, seedlings were fertigated at 0, 250 or 500 ppm Peters 20N-20P-20K. The treatments were arranged in a split plot design in three replicated blocks, where the main plot effect was liquid feed, and subplot effect was slow release fertilizer. There were 20 replicate seedlings per experimental treatment combination. After 8 weeks, plants were destructively harvested. Both liquid and slow release fertilizer main effects significantly influenced pawpaw seedling growth characteristics; however, interactions between the main effects were also significant for all growth parameters except leaf number. Overall, the seedlings subjected to the highest rate in both fertilizer methods showed the greatest total dry mass, about three fold greater than control plants.

Effect of several beetle-active *Bacillus thuringiensis* products on life history attributes of lesser grain borer, *Rhyzopertha dominica*. BRYAN D. PRICE,* JOHN D. SEDLACEK, and ANTHONY M. HANLEY, Community Research Service, Kentucky State University, Frankfort, KY 40601.

The lesser grain borer (*Rhyzopertha dominica*) (LGB), causes extensive damage to stored grains, especially wheat, and is considered a primary insect colonizer, feeding on intact kernels and developing entirely inside the grain. Artificial wheat kernels (pellets) were prepared in our laboratory by combining ground wheat, corn starch, wheat gluten and water. Pelleting techniques are a convenient way to examine the effects of various pesticides and other compounds on life history attributes of internally feeding insects. The kernels were used to bioassay several Bt products, Novodor™, Raven™ and Foil™, against the LGB, and were composed of 51% corn meal, 26% corn starch, 9% wheat gluten and 14% water. The appropriate amount of each Bt product was added at a concentration of 500 ppm active ingredient. Ten kernels of each treatment, including control, were placed in five vials. Eight LGB adults were placed into each vial, then placed randomly in a small plastic container. The adults were removed from the kernels after seven days and adult mortality quantified. Surviving adults were then transferred to another set of vials containing untreated kernels to determine any effect on fecundity. Both sets of vials were observed until all progeny emerged, then the number of progeny and development time were determined. There was no significant difference in adult survivorship among the different Bt products, but preliminary data indicates emergence from Raven and Foil treatments were significantly reduced from control. Also, development times were longer with those treatments. Fecundity data will also be presented.

Influence of Cry1AaAbAc2A *Bacillus thuringiensis* delta-endotoxin on a non-target parasitoid, *Habrobracon hebetor*. LOUIE RIVERS III,* ANTHONY M. HANLEY, BRYAN D. PRICE, and JOHN D. SEDLACEK, Land Grant Program, Kentucky State University, Frankfort, KY 40601.

Interest in biological control of stored grain pests has increased with decreasing efficacy of organophosphorus insecticides, perceived risks of toxic residues, the Food Quality Protection Act of 1996, and the Montreal Protocol. *Bacillus thuringiensis* (Dipel® [Cry1AaAbAc2A]) has been found to be effective against the Indian meal moth (IMM) in stored grains. *Habrobracon hebetor* is an efficient parasitoid of IMM. However, no studies have been conducted to determine whether or not Bt and *H. hebetor* are compatible methods of control. Thus, the objective of this research is to quantify the impact of Bt on several *H. hebetor* life history attributes. Ten treated larvae were placed into three 20 ml plastic vials per treatment with three replicates. Two male and one female *H. hebetor* adults were added to each vial and allowed to oviposit for 24 hours, then were removed. Number of progeny and longevity were determined. Progeny were placed in vials in the previous ratio and allowed to oviposit on ten additional larvae for 24 hours. Parasitoids were moved to vials of fresh larvae daily until female death. Total number of progeny and their development time were determined. All rearing and experiments were conducted in an environmental chamber at 27°C, ≥60% relative humidity and in total darkness. Progeny production and longevity of F_1 and F_2 individuals were the same between treatments. Thus, it appears as though Dipel does not have a negative impact on the parasitoids. Longer term experiments constituting multiple generations should be performed as should behavioral assays.

Insect fauna of ear corn stored in cribs on small farms in Kentucky. JOHN D. SEDLACEK,* BRYAN D. PRICE, and ANTHONY M. HANLEY, Kentucky State University, Frankfort, KY 40601.

Storing ear corn in corn cribs is practiced by many small and limited resource farmers in the central Kentucky area. Approximately 53% of all corn cribs in Kentucky are located in this region and as much as 30% of the total corn acreage and 75% of those storing corn on-farm in individual counties store it in this manner. Ear corn is more susceptible to attack by insects and fungi for the duration of storage because it is completely exposed. This past storage season we sampled ear corn in 15 corn cribs on small farms in Casey, Christian, Franklin, and Metcalfe counties. Thus far we have identified 18 species or species groups of beetles and 3 species of moth pests. The major species of beetles are maize weevil, foreign grain beetle, flat grain beetle, and hairy fungus beetles. The major moth species were Indian meal moth and Angoumois grain moth. Large numbers of parasitoids in the families Braconidae and Pteromalidae were also found. Results will be discussed relative to bin stored corn pests and potential effects of transgenic Bt hybrids in storage.

CELLULAR & MOLECULAR BIOLOGY

Transcription factor isoform-specific regulation of pituitary hormone gene expression. SCOTT E. DIAMOND* and AMY L. FERRY, Department of Physiology, University of Kentucky College of Medicine, Lexington, KY 40536-0298.

We do not yet fully understand the mechanisms by which related transcription factor isoforms with identical DNA sequence specificity mediate distinct transcription responses. Pit-1 and Pit-1b direct proper development of and hormone expression by the anterior pituitary, and constitute such a pair of transcription factor isoforms. While Pit-1 and Pit-1b share identical DNA binding domains, they differ by the splice-mediated insertion of the 26 amino acid b-domain in the transactivation domain. Pit-1 and Pit-1b regulate prolactin gene expression in opposite ways; Pit-1 activates the prolactin promoter, yet Pit-1b represses basal prolactin promoter activity as well as Ras signaling to the prolactin promoter. We have previously demonstrated that the amino acid sequence of the b-domain dictates isoform-specific repression. Here, we utilize epitope- and alanine-scanning mutagenesis experiments to identify specific residues of the b-domain insertion that dictate repression of prolactin gene expression. We demonstrate by pharmacological and molecular genetic methods that b-isoform repression requires the action of a histone deacetylase complex. In addition, we utilize a chromatin immunoprecipitation assay to show that Pit-1b specifically alters the histone acetylation state of the prolactin promoter. These findings provide significant insights into the structural determinants and mechanism of an important example of transcription factor isoform-specific regulation of gene expression.

GEOLOGY

Nature and origin of the Cane Run Bed, Lexington Limestone, central Kentucky. H. LISA JEWELL* and FRANK R. ETTENSOHN, Department of Geological Sciences, University of Kentucky, Lexington, KY 40506-0053.

Much of the Middle Ordovician Lexington Limestone represents coarse, bioclastic deposition on a shallow-water, carbonate ramp subject to frequent storm perturbation. In fact, position of the Lexington area in a subtropical, trade-wind belt on the southeast margin of Laurentia during Middle Ordovician time supports the predominance of storm or tempestite deposition in the Lexington Limestone. In contrast to most of the Lexington Limestone, however, the Cane Run Bed, which occurs in the uppermost Grier Member, is composed of interbedded fine-grained limestones and shales, which exhibit secondary, soft-sediment deformation. Moreover, the Cane Run grades laterally into coarser grained limestones of the Tanglewood and Grier members, which at the approximately equivalent horizon are also locally deformed. Mapp distribution of the fine-grained Cane Run Bed show it was deposited in a paleobathymetric low between structural trends that formed high areas during Lexingt deposition. Hence, the fine-grained nature of the Can Ru Bed reflects storm deposition in deeper water, distal environments, while coeval parts of the Tanglewood and Grier represent storm deposition in shallower waters on adjacent, uplifted structural highs. The prominent soft-sediment deformation in the Can Run Bed and its equivalents not only provides correlation among different lithologies and facies, but indicates the necessity of likely seismic activity for deformation (seismites) on one of the structures. Presence of probable seismites in proximity to local structures suggests reactivation of those structures and is additional support for the impact of Taconian far-field forces in the area during the ongoing Taconic tectophase to the east.

Possible modern analogues to bryozoan bioherms in the Tanglewood and Grier members, Lexington Limestone, central Kentucky. JASON R. LAMBERT,* FRANK R. ETTENSOHN, and ANDREA L. HOLBROOK, Department of Geological Sciences, University of Kentucky, Lexington, KY 40506-0053.

In equivalent parts of the Middle Ordovician Grier and Tanglewood members of the Lexington Limestone, just below the Brannon Member, a horizon of bryozoan bioherms is known from three localities. The bioherms are sitting on a hardground surface, surrounded by coarse, crossbedded, fossil-fragment calcarenites. The bioherms are no more than a meter high and at most a meter and a half in breadth. Upper portions of the bioherms are composed of massive, but intricately encrusting platy bryozoans, whereas lower parts typically show branching or ramose bryozoans arranged around the base of the bioherm. On the east-facing, oceanward side of San Salvador Island, Bahamas, we observed within the surf zone and in deeper shoreface waters red-algae-coral patch reefs with some characteristics similar to those of the bioherms. Although the patch reefs were up to a few tens of meters in breadth and up to five meters in height, they were also attached to a hardground and surrounded by moving skeletal sands. Upper parts of the reefs in the surf zone, especially where facing out to sea, were composed of encrusting red algae. Lower parts of the reefs below the surf zone, and those reefs in deeper shoreface waters, were composed of branching corals. Water depth and exposure to the surf zone apparently controls the morphology (encrusting vs. branching) and taxonomic makeup of various reef parts. Although sizes are an order of magnitude different, comparison of the two occurrences suggests that the Ordovician bioherms occurred within an ancient surf zone and that the different morphology and taxonomic makeup of bryozoans on different parts of the bioherms may reflect a similar zonation by depth. Hence, somewhat similar modern analogues allow us to fully understand the nature and depositional environments of an unusual, biohermal horizon in the Lexington Limestone.

Tectonic control of Sunbury (Kinderhookian) and Borden (Osagean) deposition in northeastern Kentucky. CHARLES E. MASON,* Department of Physical Sciences, Morehead State University, Morehead, KY 40351; FRANK R. ETTENSOHN, Department of Geological Sciences, University of Kentucky, Lexington, KY 40506.

Deposition of the Sunbury and Borden formations in northeastern Kentucky occurred during the fourth and final tectophase (Sunbury Cycle of Ettensohn, 1994) of the Acadian Orogeny. This Sunbury Cycle began in the Kinderhookian with an unconformity at the base of the Sunbury Shale. This break in deposition was in response to convergence of a newly placed load (Avalon microplate) on the eastern craton margin (Virginia promontory). This event was followed by deformational loading throughout most of remaining early Kinderhookian time, which resulted in rapid subsidence of the Appalachian forland basin and its migration cratonward (west). The Sunbury Shale was deposited during this time. By middle Kinderhookian time, the loading-type relaxation phase of the Sunbury Cycle began with deposition of the Henley Bed of the Farmers Member of the Borden Formation. This phase reflects a deepening of the foreland basin and a concomitant eastward shift of bulge migration. During latest Kinderhookian time, carbonate turbidites were deposited in the basin, probably derived from the eastwardly migrating bulge to the west. The clastic turbidites composing the Farmers Member, deposited during early Osagean time, had an eastern source as did sediments composing the Nancy and Cowbell members of the Borden Formation. These members document the progradational infilling of the forland basin by a coarsening-upward clastic sequence during the loading-type relaxation phase of the Sunbury Cycle. The topmost member of the Borden Formation, the Nada Member (upper Osagean) records the reduction and ultimate cutoff of silicilastic sediments from the highlands to the east, related to eastward bulge uplift and migration combined with a regional eustatic lowstand. Sediment reduction is most reflected in the glauconite-rich Floyds Knob Bed in the Nada and equivalent units.

New observations on *Brachiospongia digitata* (Hexactinellidae, Porifera) from the Middle Ordovician of Central Kentucky. DANIEL J. PHELPS,* Kentucky Paleontological Society, Lexington, KY 40503; RICHARD TODD HENDRICKS, Bardstown, KY 40004.

Recent discoveries of *Brachiospongia digitata* from the Curdsville Member of the Lexington Limestone (Middle Ordovician, Trentonian), shed light on the ecology and taxonomy of *Brachiospongia*. *Brachiospongia* specimens are present in an exposure of the Curdsville Member in outcrops adjacent to the Kentucky River Fault Zone. Individuals range from 8 to 35 cm in diameter and occur as complete or macerated specimens in fining-upward sequences ranging from calcarenites and calcisiltites to organic-rich, fissile, shales. The sponges are filled with lithified sediment; some are compacted and distorted. In one bed, the sponges are in life position, and relatively undistorted. In other beds, sponges are associated with depressions adjacent to lithified and bored mounds on hardground surfaces. In these lenses, virtually all *Brachiospongia*, even the largest specimens, are overturned or otherwise displaced from life position. This suggests transport and mutilation of the sponges during storm events. Faunas associated with the sponges include bryozoans, dendritic graptolites, crinoids, a paracrinoid, and other echinoderms. Trilobites, including articulated specimens of *Ceraurus* sp., have been found inside *Brachiospongia*, suggesting that trilobites interacted with sponges, perhaps for shelter. Some specimens of *B. digitata* display areas in which the body of the sponge is broken away to reveal an internal mold or an internal structure that is covered with tubercles and a thin layer of black materials. These tubercles are similar to those found on *Brachiospongia tuberculata* (James). These details suggest that *B. tuberculata* specimens represent internal molds of *B. digitata*, and that *B. tuberculata* is synonymous with *B. digitata*.

HEALTH SCIENCES

Unintentional influence on diet quality of taste panelists. MARTHA A. MARLETTE* and SUSAN B. TEMPLETON, Human Nutrition Program, Kentucky State University, Frankfort, KY 40601.

A taste panel to determine the acceptance of popular African-American foods modified to improve nutrient content was conducted for 10 weeks. Thirty-one African Americans, 58% female and 71% under age 30, served as panelists; 24 hr food recalls were collected from them at the initial training session and during the exit interview. Intakes were analyzed using Nutritionist V™. The panelists were given charts indicating the calories, total fat, saturated fat, cholesterol and dietary fiber content of the foods to be evaluated. Panelists reported the same number of food items on both recalls. However, the quality of dietary intake had improved in several areas, based on Recommended Daily Values (RDV) for a 2000 kcal diet. Energy intake decreased from 123% to 104% RDV, total fat decreased from 161% to 115% RDV, saturated fat decreased from 172% to 121% RDV, cholesterol decreased from 118% to 79% RDV, and fiber increased from 65% to 75% RDV. These results suggest that panelists became more aware of foods they were consuming and made better food choices, because they were given fact sheets that indicated the importance of a low fat, low cholesterol and high fiber levels provided by the modified recipes. This new knowledge on the need to reduce dietary fat and cholesterol apparently improved the food choices made by the panelists. However, these data do not indicate if these reported dietary changes would be sustained by them over time as no formal nutrition education was provided.

Lead and copper in tapwater of eastern Kentucky homes: a pilot study. JOHN G. SHIBER, Division of Biological Sciences & Related Technologies, Kentucky Community & Technical College System/KCTCS, Prestonsburg Community College, Prestonsburg, KY 41653.

One hundred nine Prestonsburg Community College students, representing six eastern Kentucky counties, collected two samples each of tapwater from their homes for lead and copper analysis. The first sample was taken from their kitchen faucets (cold water tap), before anyone had used it that day (B), and the second from the same faucet, after the water had been used for a few hours (A). Seventy-three percent of the samples originated from city water supplies, 24% from private wells, and 3% from other sources (private river, reservoir or mine). Lead concentrations found in the (B) samples ranged from ND (Not Detectable) to 10.20 ppb ($\bar{x} = 0.78$ ppb), and the (A) samples from ND to 5.48 ppb ($\bar{x} = 0.60$ ppb). Copper ranged in the (B) samples from ND to 0.84 ppm ($\bar{x} = 0.25$ ppm) and in (A) samples from ND to 1.19 ppm ($\bar{x} = 0.06$ ppm). No samples exceeded the EPA lead or copper "action level" of 15.0 ppb and 1.3 ppm, respectively. Although no direct correlation between type of water source and lead concentrations was attempted, 30% of the well samples had over 1 ppb of lead, while only 12% of the city water samples did. Sixty-eight percent of the students whose water source was from city supplies drink from the cold water tap, and 44% of those whose water comes from private wells do also. Overall, 61% of the students' families drink from the cold water tap, and 14% drink directly from the hot water tap. Seventy-seven percent cook with water from the hot water tap.

African American taste panelists accept nutritionally enhanced recipes for traditional foods. SUSAN B. TEMPLETON* and MARTHA A. MARLETTE, Human Nutrition Program, Kentucky State University, Frankfort, KY 40601.

African Americans face a disproportionate risk for hypertension, stroke, heart disease, diabetes, and some cancers, conditions known to be influenced by dietary factors. Analysis of the Continuing Survey of Food Intakes of Individuals 1994–1994 and National Health and Nutrition Examination Survey III (1988–1994) data revealed many food items frequently consumed by African Americans were high in fat, sugar, sodium, or cholesterol or low in fiber. Our goal was to nutritionally enhance traditional recipes for six commonly consumed items and to test their acceptability to African Americans using a multistage taste panel. Nutritionist Five™ was used to analyze the nutrient content of original and modified recipes. Blind ratings were made on taste alone; for Informed ratings, food items were identified as original or modified and the nutrient content of each was provided; for Informed-Blind ratings, nutrition information was provided, but the versions were not identified. Fifty-eight percent of the 31 African-American panelists were female; 71% were 19–30 years old. Based on a 1 (low) to 7 (high) scale, mean acceptability ratings for original/modified food iten 5.2/4.6 (Blind), 5.5/4.7 (Informed), and 5.6/5.1 (Info Blind) ($P < 0.05$). Although original items received hig ratings, over 50% of Informed panelists indicated th were equally or more likely to consume the modified ve sion. Modified item ratings improved with each tasting; at the third tasting, Informed-Blind panelists could not distinguish the modified food item from the original 35% of the time. Our findings suggest that these low fat/high fiber alternatives are acceptable to African-American panelists.

PHYSICS & ASTRONOMY

Generating solutions in Einstein-Maxwell gravity. SHARMANTHIE FERNANDO, Department of Physics and Geology, Northern Kentucky University, Highland Heights, KY 41099.

Solutions to Einstein-Maxwell gravity with cylindrical symmetry is generated. By taking the symmetries of the metric, the Lagrangian is written as a $1 + 0$ sigma model. Then, SL(2,R) transformations are applied to the functions in $1 + 0$ dimensions to generate new solutions in $3 + 1$ dimensions. Well-known electrical and magnetically charged static solutions are taken as seed metrics to generate new rotating charged solutions.

NASA Kentucky Space Grant Consortium and NOVA Program opportunities for space-related research, technology, and education. KAREN HACKNEY,* RICHARD HACKNEY, ROGER SCOTT, CHARLES McGRUDER, SANDRA CLEMENTS, MICHAEL CARINI, RICHARD GELDERMAN, TERRY WILSON, DON COLLINS, KATHI MATTHEW, and MIKE MAY, Kentucky Space Grant Consortium and NASA NOVA Programs, Department of Physics and Astronomy, Western Kentucky University, Bowling Green, KY 42101.

NASA has partnerships with Kentucky and its universities for the purpose of involving faculty and students in space-related research, technology, and education. We will describe current opportunities in the Kentucky Space Grant Consortium for undergraduate scholarships and graduate fellowships for students in mentored, space-related projects. Funding opportunities for the development of space-related research projects will be described. Activities of the NOVA and Space Grant programs that support the teaching of space-science and related disciplines will be outlined. Progress of existing projects and new opportunities will be discussed.

Digital dynamism for enlivening astronomy in the classroom. RICHARD HACKNEY,* KAREN HACKNEY, ROGER SCOTT, MICHAEL CARINI, RICHARD GELDERMAN, and CHARLES McGRUDER, Department of Physics and Astronomy, Western Kentucky University, Bowling Green, KY 42101.

Digital technology is resulting in a wealth of available, inexpensive illustrative materials for enlivening astronomy presentations in the classroom. NASA and other sources provide animated views that dynamically illustrate the motions and physical activity of objects in the universe. Students can gain a sense of personal involvement with, and the immediacy of, activity in space through timely sharing of current observational material on the web. Instructors and students can make and share direct observations of astronomical objects such as the sun and moon using simple telescopes and relatively inexpensive digital cameras. We present an assortment of sources, examples, and methods for using these resources to enliven the teaching and learning of astronomy.

Demonstrating the Ptolemaic and Copernican systems. ROGER SCOTT,* RICHARD HACKNEY, KAREN HACKNEY, MIKE CARINI, RICHARD GELDERMAN, and CHARLES McGRUDER III, Department of Physics and Astronomy, Western Kentucky University, Bowling Green, KY 42101.

Many astronomy courses include a historical perspective of how the modern concept of the Solar System was developed, and the role that Galileo's observations of the phases of Venus played. This presentation will discuss the significance of Galileo's observations, and will illustrate a simple way of demonstrating the phases of Venus in both the geocentric Ptolemaic system and the heliocentric Copernican system.

Gravitational lensing by black holes. BRIAN TALBERT and SEAN ROBERTS, Department of Physics and Geology, Northern Kentucky University, Highland Heights, KY 41099.

Lensing by charged black holes characterized by the mass and charge is studied. As a first step, we have calculated the deflection of light from a electrically charged black hole with the assumption that the gravitational field is weak and that the deflection angles of light rays are small. This approximation will lead to three images if the parameters in lensing such as the mass, the charge and the distances satisfy certain restrictions. We have done the calculations for a supermassive black hole and found the magnification of the images. The support from the Kentucky Space Grant Consortium is gratefully acknowledged.

PHYSIOLOGY & BIOCHEMISTRY

Evidence for dramatically increased bone turnover in spontaneously hypertensive rats. D. L. DeMOSS, Department of Biology, Morehead State University, Morehead, KY 40351; G. L. Wright, Department of Physiology, Marshall University School of Medicine, Huntington, WV 25704.

Using the ^{3}H-tetracycline model, whole body skeletal bone resorption was compared among male and female spontaneously hypertensive and normotensive Wistar Kyoto and Sprague-Dawley rats. Immature animals undergoing rapid skeletal growth and bone sculpting showed a tendency for decreased indices of skeletal resorption in females compared to males. By 24 weeks of age, the indices of rate of resorption and extent of metabolically reactive bone in male rats were decreased an average of 68% and 74%, respectively, compared to values obtained at 8 weeks. By comparison, values for 24 week old females decreased only 26% and 56%, respectively, resulting in evidence of a significantly elevated level of resorptive activity in mature females compared to males in each of the three rat strains studied. Within sex comparisons of 24-week-old animals indicated that bone resorptive activity was similar between normotensive male and between normotensive female groups. By comparison, the resorptive activity of both male and female hypertensive rats was significantly increased compared to normotensive controls. This condition was exaggerated in female hypertensive rats, which showed an approximate 78% and 41% increase in indices of rate of resorption and extent of metabolically reactive bone compared to normotensive controls. The results indicate a marked sexual dichotomy in the decline of skeletal bone resorptive activity following maturation and slowing of skeletal growth. They further indicate a significant elevation of whole skeleton bone turnover in male hypertensive rats and dramatically increased bone turnover in female hypertensive rats.

PSYCHOLOGY

Effects of observer type on social facilitation. TIM KRAEMER and BONNIE BOWERS, Centre College, Danville, KY 40422.

This experiment, which concerns the effects of observer type on social facilitation for a learning task, was modeled after the research of Henchy & Glass (1968, cf. Gore & Taylor, 1973) and Gore & Taylor (1973). The present experiment proposed that males' and females' response time and accuracy of answers on a learning task would be quicker and more accurate for students observed by a perceived nonexpert on the task than those observed by a perceived expert on the task. Forty Centre College students, 25 males and 15 females with a mean age of 19.83, completed the Zinbarg learning task on standard college computers, while being observed by a perceived expert/nonexpert or not being observed (control condition). The hypothesis was partially supported, such that only females' scores showed social facilitation in that their performance was quicker and more accurate in the nonexpert condition than in the expert condition.

SCIENCE EDUCATION

Fear of algebra. JOHN G. SHIBER, Division of Biological Sciences & Related Technologies, Kentucky Community & Technical College System/KCTCS, Prestonsburg Community College, Prestonsburg, KY 41653.

Frequent comments by community college students, especially non-traditional students, about disliking and fearing algebra, prompted a survey to learn the extent of the problem, and if there were similar fears of biology, chemistry or physics. Three hundred seventy-seven community college students (40% non-traditional) responded. Most had taken algebra, and 53% disliked or feared it. Twenty-six percent and 22%, respectively, feared chemistry and physics. Non-traditionals were more prone to fear all. Biology was least feared. Six hundred sixty-seven Eastern Kentucky high school seniors completed the survey for comparison purposes. Only 14% feared algebra, but many feared calculus, i.e., 40% who had taken it and 48% who hadn't. Twenty-four percent feared chemistry and physics, 30% of females vs. 18% of males feared physics, and biology, again, was least feared. Students blamed their fears of algebra and calculus on a lack of confidence, e.g., "can't understand it," "too confusing," "not good at math," etc. Suggestions for improving the courses, though, reflected need for better instructional approaches, wanting teachers to go slower, explain more in depth, and have more hands-on and real-life applications. Many high school seniors wanted more knowledgeable instructors who are interested in math and student learning. It is concluded that a perceptual problem among students that labels math in general, and algebra and calculus in particular, as too difficult for the average person, does indeed exist, and is often perpetuated by teachers and counselors. A more positive attitude about math when dealing with students, and a more concerted effort by all educators to remedy the problem, is urged.

Student survey on violence. JOHN G. SHIBER, Division of Biological Sciences & Related Technologies, Kentucky Community & Technical College System/KCTCS, Prestonsburg Community College, Prestonsburg, KY 41653.

The wave of concern in recent years about school violence prompted a survey on the issue at Prestonsburg Community College. Sixty-three percent of 307 students responding have weapons in their homes; 59% have more than one. Eighty-eight percent of them have rifles, 70% handguns, and 43% large knives. The weapons are used chiefly for hunting (33%), personal protection (25%), or both (27%). Twenty-nine percent of the students have children at home, 51% of whom are under 15 years of age. Over half know where the weapons are kept, and 23% could get them if they wanted. Of all students surveyed, 58% often watch movies with a lot of violence, and 50% believe children under 18 should be admitted to "R-rated" movies. Only 17% play video games that are violent in nature. When very angry, 48% resort to some form of violent behavior, e.g., slamming doors, throwing things, screaming, hitting something (or someone), etc. Thirty-three percent have been in serious physical fights, and 64% have witnessed them in school. According to many, most school fights are over the opposite sex (36%) and kids teasing or spreading rumors about each other (25%). Twenty-six percent had seen students with weapons in school, but few told an adult about it, for fear of repercussions. While attributing teen violence to many factors, students most frequently mentioned the lack of parental/guardian supervision and guidance. Parents of violent teens, said a majority, are partially, if not entirely to blame for their offsprings' behavior. Temporary suspension or permanent expulsion, with some type of police involvement, was most commonly suggested as a punishme students bringing weapons to school.

ZOOLOGY & ENTOMOLOGY

Abiotic factors as predictors of terrestrial vertebrate species richness in Kentucky. MATTHEW L. COLE* and TERRY L. DERTING, Department of Biological Sciences, Murray State University, Murray, KY 42071.

On a global scale, abiotic factors, particularly those associated with climate, have significant impacts on species richness. Climate variables have been used successfully in models that predict large-scale variation in species richness. We tested the utility of abiotic factors as predictors of species richness at the regional level. Using regression analysis, we developed models to predict the combined richness of terrestrial vertebrate species in Kentucky and the species richness of amphibians, breeding birds, mammals, and reptiles. The abiotic variables used in our models were precipitation, temperature, elevation, topographic variation, and road density. The resulting models were generally effective, accounting for ≈50% or more of the variation of species richness in the state. Temperature, precipitation, and elevation were of primary importance in all models. Temperature alone was the best predictor of total species richness ($r^2 = 0.56$). Elevation and temperature together were the best predictors of the species richness of breeding birds ($r^2 = 0.49$), mammals ($r^2 = 0.48$), and reptiles ($r^2 = 0.75$). Abiotic variables were less effective as predictors of the species richness of amphibians, however. Elevation and precipitation yielded the best predictive model but explained only 22% of the variation in amphibian species richness. As with global models, abiotic factors accounted for a significant amount of regional variation in species richness. Through future modeling efforts we will determine the extent to which biotic factors improve predictions of species richness in Kentucky.

Mate selection of male *Poecilia reticulata*. GREG DARNELL* and ZACHARY McCARTY,* Department of Biology, Transylvania University, Lexington, KY 40508.

Our experiment hypothesized that when male guppies (*Poecilia reticulata*) were given the chance to select a potential mate, they would prefer the larger of two female guppies. To run trials, a test tank was setup with three clear partitions to divide the tank into three equally sized chambers. Different sized females were placed in the outer chambers and a male was released in the middle. Trials were run for 15 minutes and data were collected based upon how much time the male spent in the vicinity of each female. All guppies were measured after the completion of each trial and new guppies being used in the following trial. Of the 16 males tested, 12 preferred the large female, 3 preferred the smaller female, and 1 showed no preference. Using the sign test to analyze these data, the null hypothesis stating that the male would be indifferent and spend equal time with each female was rejected with 95% confidence. Therefore, when presented with the opportunity for mate choice, male guppies discriminated and chose the larger female guppy. This may relate to the increased fertility of the large females, which produce a greater number of eggs than the smaller females.

How pattern of fruiting in tropical trees affects territory size of white-winged trumpeters. PETER T. SHERMAN,* Department of Biology, Transylvania University, Lexington, KY, 40508; PERRI K. EASON, Department of Biology, University of Louisville, Louisville, KY 40292.

We investigated determinants of territory size in white-winged trumpeters (*Psophia leucoptera*), which are group-living, frugivorous birds that defend large, permanent territories in Amazonian rainforest. During a 7-month period, we measured changes in food density at a site in Manu National Park, Peru, and conducted full-day focal samples on individuals that allowed us to record daily food intake of territorial birds. Both census and focal sample data suggested that food availability on trumpeter territories varied widely. To determine whether trumpeter territory size is related to food density, we conducted fruit removals during which we removed daily an amount of fruit from the territory that was equivalent to the amount of fruit ingested daily by the focal group during a control period that preceded the removal experiment. Trumpeter food consumption did not change when fruit was removed during periods of resource abundance, but, when experimental removals were conducted during times when food was scarce, total caloric value of food consumed decreased significantly. Our results suggest that food abundance on trumpeter territories sometimes exceeds and sometimes is close to or below the amount needed to meet the energetic needs of the groups. Based on data collected, we propose that territory size of trumpeter groups reflects some minimum size needed to provide the group with a baseline level of food intake during seasonal periods of decreased food abundance.

Swamp rabbit habitat modeling using a geographic information system. ADAM SMITH* and TERRY DERTING, Department of Biological Sciences, Murray State University, Murray, KY 42071.

Using a geographic information system (GIS), we developed three models predicting the occurrence of swamp rabbits (Sylvilagus aquaticus) in western Kentucky. The models were compared to the existing Kentucky GAP model. All models were successful in the prediction of confirmed swamp rabbit observations, both of presence (>80%) and absence (>90%), with only slight variation among models. After selection of the best model based on statistical performance and model construction criteria, the best model was applied to geographic areas of Kentucky contiguous to the species' current Kentucky range to investigate the possibility of swamp rabbit reintroductions. Only five areas for potential reintroduction were identified, with two of marginal quality and the remaining unsuitable for swamp rabbit reintroduction. Land ownership and protection status of all habitat determined to be suitable by our best model was assessed; the vast majority of all land was in private ownership. Wildlife Management Areas protected the most swamp rabbit habitat (≈8%), but most suitable habitat remains at risk. These models can serve as a solid basis for future swamp rabbit management considerations. Field validation and frequent assessments and modifications of the models associated with increased data availability and improved GIS technology are recommended.

Guidelines for Contributors to the Journal

1. GENERAL

A. Original research/review papers in science will be considered for publication in JKAS; at least the first author must be a member of the Academy. Announcements, news, and notes will be included as received.

B. Acceptance of papers for publication in JKAS depends on merit as evaluated by each of two or more reviewers.

C. Papers (in triplicate) may be submitted at any time to the editor. Do not send a disk file.

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List in the cover letter your telephone number, your e-mail address, and the names, addresses, and telephone numbers of two persons who are potential reviewers.

D. Format/style of papers must conform to these guidelines and also to practices in recent issues of JKAS, which are, in effect, a style manual.

E. Papers should be submitted in hard copy. Do not staple pages together.

F. Indent the first line of each paragraph (but not the first line of entries in the Literature Cited).

2. FORMAT

A. Papers should be in 12-point type on white paper 8.5 × 11 inches, with margins at least 1 inch all around. Double-space throughout the paper (i.e., one full line of space between each two lines of text, literature cited, or tabular data). Do not justify right margins.

B. Except for scientific names of genera and of infrageneric taxa, which should be typed in italics, the same type (roman) should be used throughout (i.e., one type size only; bold only for paper title).

C. Sequence of sections in papers should, where appropriate, be as follows: title of paper, name/address of author(s), abstract, body of paper, footnotes, table captions, figure captions (all the preceding on consecutively numbered pages), tables, and figures.

D. The running head (top right) should give name(s) of author(s), a short version of paper title, and page number of total.

E. The first page should include the running head and, centered near the top of the sheet, the paper's title and the name and address of author(s). These should be followed immediately by the abstract. (The first page should look as much as possible like the first page of articles in JKAS.)

F. The abstract, not to exceed 200 words, should be concise, descriptive, and complete in itself without reference to the paper.

G. The body of the paper should, where appropriate, include the following sections: Introduction, Materials and Methods, Results, Discussion, Summary, Acknowledgments, and Literature Cited.

H. No more than three levels of headings should be used: level 1, in capitals, centered; level 2, in capitals/lowercase, flush left; level 3, in italics, a paragraph indent, with initial capital only (except proper nouns and adjectives), and followed by a period, the text then starting after one blank space.

I. Personal communications (avoid if possible) should be indicated in the text as follows: (name, affiliation, pers. comm., date), e.g., (O.T. Mark, Wainwright College, pers. comm., 5 Jun 1995).

3. STYLE

A. In text, spell out one-digit numbers unless they are used with units of measure (four oranges, 4 cm) and use numerals for larger numbers; do not begin any sentence with a numeral.

B. Use no footnotes except those for title page and tables. Footnotes, identified by consecutive superscript numbers, should be entered on a separate sheet.

C. Measurements should be in metric and Celsius units. Define lesser-known symbols and give the meaning of acronyms at first use. Express time of day in the 24-hour system. Dates should be written day, month (abbreviated to three letters), year without internal punctuation. Units with multiple components should have individual components separated by a virgule (e.g., g/m^2 or $g/m^2/yr$).

D. Names of authors of binomials may be included but only at the first mention of the binomial. Cultivar names are not italicized but are enclosed in single quotes.

E. Useful guides for contributors to JKAS are the following: *Scientific style and format: the CBE manual for authors, editors, and publishers,* 6th ed., Cambridge University Press, 1994; *The Chicago manual of style,* 14th ed., University of Chicago Press, 1993; *The ACS style guide,* American Chemical Society, Washington, DC, 1986; and *AIP style manual,* American Institute of Physics, New York, 1990.

4. IN-TEXT CITATION OF LITERATURE

A. Cite publications in the text by author(s) and date—e.g., (Readley 1994); multiple citations should be in alphabetical order and separated by semi-colons—e.g., (Ashley 1987; Brown 1994; Foster 1975); multiple citations of works by one author(s) should be in chronological order—e.g., (Jones 1978, 1983); publications by one author(s) in the same year should be distinguished by a, b, c, etc.—e.g., (Smith 1994a, 1994b). For in-text references to works with one or two authors use names of both authors—e.g., (Jones and Williams 19[illegible]); for works with three or more authors use name of the first author followed by et al.—e.g., (Lee et al. 1985).

B. Do not include any reference unless it has been published or accepted for publication ("in press"; see below).

5. LITERATURE CITED

A. List all authors of each entry. Do not abbreviate journal titles; abbreviations for these will be supplied by the editor.
B. The first line of each reference should be typed flush left; the remaining lines should be indented.
C. Examples of common types of references are given below.

JOURNAL ARTICLE

Lacki, M.J. 1994. Metal concentrations in guano from a gray bat summer roost. Transactions of the Kentucky Academy of Science 55:124–126.

BOOK

Ware, M., and R.W. Tare. 1991. Plains life and love. Pioneer Press, Crete, WY.

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

Groves, S.J., I.V. Woodland, and G.H. Tobosa. n.d. Deserts of Trans-Pecos Texas. 2nd ed. Ocotillo Press, Yucca City, TX.

6. ILLUSTRATIONS

FIGURES (LINE DRAWINGS, MAPS, GRAPHS, PHOTOGRAPHS)

Figures must be camera-ready, glossy, black-and-white prints of high quality or laser prints of presentation quality. These should be designed to use available space effectively: a full page or part of one, or a full column or part of one. They should be mounted on heavy white board and covered with a protective sheet of paper; photographs to be grouped as a plate should have no space between them. Dimensions of plates must observe page proportions of the journal. Each illustration in a plate may be numbered as a separate figure or the entire plate may be treated as one figure. Include scale bars where appropriate. Lettering should be large enough to be legible after reduction; use lowercase letters for sections of a figure. Figure captions should be self-explanatory without reference to the text and should be entered on a page separate from the text. Number figures in Arabic numerals. Statistics presented in figures should be explained in the caption (e.g., means are presented ± SE, n = 7).

TABLES

Each table and its caption must be double-spaced, numbered in Arabic numerals, and set on a sheet separate from the text. The caption should begin with a title relating the table to the paper of which it is a part; it should be informative of the table's contents. Statistics presented in the table should be explained in the caption (e.g., means are presented ± SE, n = 7).

7. ETHICAL TREATMENT OF ANIMALS AS RESEARCH SUBJECTS

If vertebrate or invertebrate animals are involved in a research project, the author(s) should follow those guidelines for ethical treatment of animals appropriate for the subjects, e.g., for mammals or for amphibians and reptiles. Papers submitted to JKAS will be rejected if their content violates either the letter or the spirit of the guidelines.

8. PROOFS

Authors are responsible for correcting proofs. Alterations on proofs are expensive; costs will be assessed to authors. Proofs must be returned to the editor within 3 days after the author receives them; delay in return may result in delay of publication.

9. REPRINTS

Forms for ordering reprints will be sent to the author when the proofs are sent. They are to be returned directly to Allen Press, not to the editor.

10. PAGE CHARGES

A page charge covering the partial cost of publication will be assessed for all authors. However, acceptance or rejection of an individual manuscript is determined solely on scientific merit. Individuals may contact the KAS office (Kentucky Academy of Science, Science Outreach Center, University of Kentucky, Lexington, KY 40536-0078) to request an application form for full or partial remission of page charges. The application form is also posted on the KAS website. Awards are limited to available funds.

11. ABSTRACTS FOR ANNUAL MEETINGS

Instructions on style of abstract preparation for papers presented at annual meetings may be obtained from the editor. Copies will be available also at each annual meeting of the Academy.

NEWS

The *Morehead Electronic Journal of Applications in Mathematics* (MEJAM) is a new interdisciplinary journal sponsored by Morehead State University, Morehead, Kentucky. The goal of MEJAM is to provide a refereed outlet for undergraduate students in any discipline to publish quality papers and see the results quickly. MEJAM accepts papers that are outside the realm of the typical undergraduate curriculum and that emphasize the applications of mathematics while maintaining significant mathematical interest. Papers may be historical, expository, or completely original in nature but must adhere to strict academic standards and must emphasize some aspect of the applications of mathematics. Papers from all disciplines will be considered for publication. More information about the journal and instructions for submissions can be found on the journal's website at http://www.morehead-st.edu/colleges/science/math/mejam/.

The Kentucky Academy of Science is seeking to complete its set of *Transactions of the Kentucky Academy of Science*. Various issues prior to 1985 are needed. Anyone willing to donate back issues or to sell them at a reasonable price should get in touch with the editor at thieretj@nku.edu.

The 2001 annual meeting of the Kentucky Academy of Science will be held jointly with the Tennessee Academy of Science on Thursday—Saturday, 29–30 November and 1 December 2001, at Middle Tennessee State University (MTSU), Murfreesboro, Tennessee. There will be a reception and symposium at the Garden Plaza Hotel in Murfreesboro on Thursday evening. Friday technical sessions will be help on the MTSU campus in the Keathley University Center and James Union Building. The annual awards banquet and president's reception will be held Friday evening at the Garden Plaza Hotel. Technical sessions will conclude on Saturday in the Keathley University Center.

PUBLICATIONS

The *Sibley Guide to Birds* from the National Audubon Society is now available. This 544-page work, written and illustrated by David Allen Sibley, covers North America north of Mexico. Families and, in some cases, genera are introduced with small figures for initial comparisons. Each group is followed by individual species accounts including figures of the different forms and phases that may be exhibited by each species and also of both perching and flying views. The book has ca. 6600 illustrations (paintings) and descriptions of 810 species and 350 regional populations; it is more a reference source than a field manual. The introductory chapter briefly discusses classification and techniques of field ornithology. A second chapter discusses and illustrates the topography of birds. *Sibley* concludes with an index to common and scientific names of species. The book is a Chanticleer Press edition published in 2000 by Alfred A. Knopf, Inc.; ISBN 0-679-45122-6; $35.00 (soft cover).

The *National Audubon Society Field Guide to Wildflowers. Eastern Region* is a revision of the first edition of the work (1979); the revising author is John W. Thieret. This 879-page book has all new photographs of 638 species, two or three per page. The introductory pages discuss the arrangement of the color plates (mostly by color and type of flower cluster), flower parts, inflorescence type, leaves, and plant classification and names. For each included species the text gives a description, flowering times, habitat, range, and comments. Relevant families are briefly discussed. The book concludes with an index to common and scientific names of species. The book is a Chanticleer Press edition published by Alfred A. Knopf, Inc., in 2001; ISBN 0-376-40232-2; $19.95 (soft cover).

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