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Pachybrachis trinotatus (F. E. Melsheimer) (Coleoptera: Chrysomelidae: Cryptocephalinae) from Kentucky. See article by Barney, Clark, and Riley, page 3 of this issue.

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Annotated List of the Leaf Beetles (Coleoptera: Chrysomelidae) of Kentucky: Subfamily Cryptocephalinae

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ABSTRACT

An examination of leaf beetle specimens (Coleoptera: Chrysomelidae) in the largest beetle collections in Kentucky, recent inventory work in state nature preserves and other protected areas, and a review of the literature revealed 59 species of Cryptocephalinae present in Kentucky, 27 of which were previously unreported for the state. Distribution maps and label data are presented for the 59 Kentucky species, including spatial (state and Kentucky county records), temporal (years and months of collection in Kentucky), and plant association information. The following species are reported from Kentucky for the first time: *Griburius scutellaris* (F.), *Pachybrachis bivittatus* (Say), *Pachybrachis confusus* Bowditch, *Pachybrachis diversus* Fall, *Pachybrachis hepaticus hepaticus* (F. E. Melsheimer), *Pachybrachis luridus* (F.), *Pachybrachis morosus* Haldeman, *Pachybrachis obsoletus* Suffrian, *Pachybrachis othonus othonus* (Say), *Pachybrachis peccans* Suffrian, *Pachybrachis pectoralis* (F. E. Melsheimer), *Pachybrachis praeclarus* Weise, *Pachybrachis spumarius* Suffrian, *Pachybrachis trinotatus* (F. E. Melsheimer), *Pachybrachis viduatus* (F.), *Bassareus lituratus* (F.), *Cryptocephalus calidus* Suffrian, *Cryptocephalus fulguratus* J. L. LeConte, *Cryptocephalus gibbicollis decrescens* R. White, *Cryptocephalus mutabilis* F. E. Melsheimer, *Cryptocephalus notatus* F., *Cryptocephalus striatulus* J. L. LeConte, *Diachus catarius* (Suffrian), *Diachus chlorizans* (Suffrian), *Triachus atomus* (Suffrian), *Coleopthorpa dominicana franciscana* (J. L. LeConte), and *Neochlamisus gibbosus* (F.).

KEY WORDS: Kentucky, leaf beetles, Coleoptera, Chrysomelidae, Cryptocephalinae, biodiversity, new state records

INTRODUCTION

This paper is the seventh and final in a series intended to present a synopsis of the historical collection data on leaf beetles (Coleoptera: Chrysomelidae) from the major Coleoptera collections in Kentucky and augment those data with new information gained from recent monitoring in state preserves and other protected locations. The first six papers presented information on the subfamilies Cassidinae (Barney et al. 2007), Donaciinae and Criocerinae (Barney et al. 2008a), Chrysomelinae (Barney et al. 2008b), Galerucinae, tribes Galurucini and Luperini (Barney et al. 2009a), Galerucinae, tribe Alticini (Barney et al. 2009b), and Eumolpinae (Barney et al. 2010).

The subfamily Cryptocephalinae is known as the case bearers due to the fact that the larvae inhabit self-constructed cases built from a combination of fecal pellets, soil particles and plant detritus (LeSage 1982, 1984a, 1984b, 1986; Stiefel 1993; LeSage and Stiefel 1996). Cryptocephalinae is a moderate-sized group with over 340 species in 22 genera in America north of Mexico (Riley et al. 2002). Several reviews of cryptocephaline genera have been conducted including those treating *Pachybrachis* (Fall 1915), *Lexiphanes* (Balsbaugh 1966), *Exema* (Karren 1966), and *Cryptocephalus* (White 1968), and the subfamilies (now tribes) Clytrinae (Moldenke 1970) and Chlamisinae (Karren 1972).

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The purpose of this study is to present historical and current knowledge of the distribution, abundance, and plant associations of cryptocephaline leaf beetles in Kentucky.

MATERIALS AND METHODS

To establish a historical perspective, leaf beetle specimens from the major insect collections in Kentucky (and from collections located in other states but known to contain Kentucky specimens) were examined, re-identified, and their label data recorded. The following collections were studied with the timeframe of their Kentucky specimens listed:

CMC	Cincinnati Museum Center, Cincinnati, OH 1871–1931
UKIC	University of Kentucky Insect Collection, Lexington, KY 1889–1993
WKUC	Western Kentucky University Collection, Bowling Green, KY 1958–2006
RJBC	Robert J. Barney Collection, Winfield, WV (private) 1983–2009
BYUC	Brigham Young University Collection, Provo, UT 1988–2009
CWC	Charles Wright Collection, Frankfort, KY (private) 1991–2009
KYSU	Kentucky State University Collection, Frankfort, KY 2004–2009

The Cincinnati Museum Collection, formerly known as the Cincinnati Museum of Natural History, houses the Charles Dury Collection comprising approximately 75,000 specimens primarily collected in the Cincinnati/northern Kentucky area (Vulinec and Davis 1984). Most of the leaf beetles have a label reading "Ky. near Cin. O." They usually have no date. When a Dury specimen was the first or only specimen collected for a particular species, we have used "pre-1931" as an approximate collection date.

The Kentucky State University Insect Collection is primarily the specimens generated by the Kentucky Leaf Beetle Biodiversity Project. We conducted extensive collecting in many grass-dominated barrens and rock outcrop (glade) communities that are known for possessing uncommon plants and plant associations (Jones 2005) and have never been surveyed for leaf beetles. These sites are managed by the Kentucky State Nature Preserves Commission, The Nature Conservancy, and the United States Army at Fort Campbell Military Reservation (Baskin et al. 1994). Most specimens were collected by the senior author within five state nature preserves in 2004–2009 and Fort Campbell in 2008–2009: Crooked Creek Barrens (Lewis County) and Blue Licks Battlefield (Robertson County) in northeastern Kentucky, Eastview Barrens (Hardin County) and Thompson Creek Glades (LaRue County) in central Kentucky, and Raymond Athey Barrens (Logan County) and Fort Campbell (Christian and Trigg Counties) in western Kentucky.

For each cryptocephaline species documented for Kentucky, the following data are presented: state-level distribution in the United States (from Riley et al. 2003), Kentucky county records, abundance by year and month in Kentucky, and specimens per collection. Other pertinent information present on specimen labels, such as the method of collection and plant association information, is presented in the "Comments" section for each species. This information helps to determine abundance, seasonality, and distribution from a historical perspective. Barney and Hall (2011) reported host plant data for 23 species of cryptocephalinaes in Kentucky. One should note that plant collection records taken from specimen labels are notoriously inaccurate and may not reflect true host plants (Clark et al. 2004).

RESULTS

According to the "Catalog of Leaf Beetles of America North of Mexico" (Riley et al. 2003), there are 102 species of Cryptocephalinae recorded in at least one of the seven states contiguous to Kentucky. However, only 32 species were reported from Kentucky. An examination of 2753 cryptocephalinae leaf beetle specimens from the major collections in the state and others known to contain Kentucky specimens revealed 59 species including 28 of the 32 recorded in Riley et al. (2003) and 27 new state records (Table 1). Three of the four species listed by Riley et al. (2003) as being from Kentucky but not recovered in this study were *Neochlamisus*, two of which were reported by Karren (1972).

Table 1. List of Cryptocephalinae (Coleoptera: Chrysomelidae) recorded from Kentucky, with number of Kentucky specimens examined, number of Kentucky county records, range of years of collection in Kentucky, and new state records.

Tribe Cryptocephalini	
Griburius scutellaris (F.)	71 specimens: 10 counties, 1970–2009 (new state record)
Pachybrachis atomarius (F. E. Melsheimer)	55 specimens: 3 counties, 1985–2009
Pachybrachis bivittatus (Say)	11 specimens: 5 counties, 1971–1998 (new state record)
Pachybrachis confusus Bowditch	23 specimens: 3 counties, 1976–2009 (new state record)
Pachybrachis diversus Fall	2 specimens: 2 counties, 1972 (new state record)
Pachybrachis hepaticus hepaticus (F. E. Melsheimer)	8 specimens: 4 counties, 1894–2009 (new state record)
Pachybrachis luridus (F.)	11 specimens: 4 counties, 1970–2009 (new state record)
Pachybrachis m-nigrum (F. E. Melsheimer)	74 specimens: 4 counties, 1971–2009
Pachybrachis morosus Haldeman	25 specimens: 2 counties, 2005–2009 (new state record)
Pachybrachis nigricornis carbonarius Haldeman	286 specimens: 9 counties, 1971–2009
Pachybrachis obsoletus Suffrian	5 specimens: 3 counties, 1971–2008 (new state record)
Pachybrachis othonus othonus (Say)	33 specimens: 6 counties, 1971–2009 (new state record)
Pachybrachis peccans Suffrian	1 specimen: 1 county, 1998 (new state record)
Pachybrachis pectoralis (F. E. Melsheimer)	10 specimens: 5 counties, 1891–2009 (new state record)
Pachybrachis praeclarus Weise	17 specimens: 2 counties, 2005–2009 (new state record)
Pachybrachis relictus Fall	unknown
Pachybrachis spumarius Suffrian	169 specimens: 12 counties, 1972–2009 (new state record)
Pachybrachis subfasciatus (J. L. LeConte)	3 specimens: 2 counties, 2003–2009
Pachybrachis tridens (F. E. Melsheimer)	1 specimen: 1 county, pre-1931
Pachybrachis trinotatus (F. E. Melsheimer)	78 specimens: 11 counties, 1966–2009 (new state record)
Pachybrachis viduatus (F.)	28 specimens: 2 counties, 2004–2009 (new state record)
Lexiphanes saponatus (F.)	17 specimens: 8 counties, 1893–2009
Bassareus clathratus (Melsheimer)	71 specimens: 17 counties, 1893–2009
Bassareus formosus (Melsheimer)	10 specimens: 4 counties, pre-1931–2009
Bassareus lituratus (F.)	153 specimens: 11 counties, 1892–2009 (new state record)
Bassareus mammifer (Newman)	12 specimens: 7 counties, 1907–2003
Cryptocephalus badius Suffrian	6 specimens: 2 counties, pre-1931–1971
Cryptocephalus calidus Suffrian	2 specimens: 2 counties, 1985 (new state record)
Cryptocephalus fulguratus LeConte	1 specimen: 1 county, 2005 (new state record)
Cryptocephalus gibbicollis decrescens R. White	1 specimen: 1 county, 1892 (new state record)
Cryptocephalus guttulatus Olivier	12 specimens: 8 counties, 1915–1995
Cryptocephalus leucomelas leucomelas Suffrian	14 specimens: 9 counties, 1894–2008
Cryptocephalus mucoreus LeConte	4 specimens: 3 counties, 1983–2009
Cryptocephalus mutabilis Melsheimer	13 specimens: 8 counties, 1894–2008 (new state record)
Cryptocephalus nanus F.	5 specimens: 4 counties, 1970–2009
Cryptocephalus notatus F.	27 specimens: 11 counties, 1939–2009 (new state record)
Cryptocephalus quadruplex Newman	24 specimens: 14 counties, 1891–2009
Cryptocephalus striatulus LeConte	54 specimens: 4 counties, 2005–2008 (new state record)
Cryptocephalus venustus F.	339 specimens: 23 counties, 1891–2009
Diachus auratus (F.)	6 specimens: 4 counties, pre-1931–1995
Diachus catarius (Suffrian)	4 specimens: 1 county, pre-1931 (new state record)
Diachus chlorizans (Suffrian)	34 specimens: 4 counties, 1972–1995 (new state record)
Triachus atomus (Suffrian)	1 specimen: 1 county, 2006 (new state record)
Tribe Clytrini	
Anomoea flavokansiensis Moldenke	71 specimens: 18 counties, 1955–2009
Anomoea laticlavia laticlavia (Forster)	115 specimens: 29 counties, 1892–2009
Coleothorpa dominicana dominicana (F.)	92 specimens: 18 counties, 1892–2009
Coleothorpa dominicana franciscana (LeConte)	1 specimen: 1 county, 2007 (new state record)
Babia quadriguttata quadriguttata (Olivier)	58 specimens: 16 counties, 1942–2009
Saxinis omogera omogera Lacordaire	274 specimens: 17 counties, pre-1931–2009
Tribe Chlamisini	
Chlamisus foveolatus (Knoch)	2 specimens: 2 counties, 1972–2004
Exema canadensis Pierce	198 specimens: 23 counties, 1971–2009
Exema dispar Lacordaire	135 specimens: 31 counties, 1971–2009
Neochlamisus bebbianae (Brown)	9 specimens: 4 counties, 2005–2008
Neochlamisus bimaculatus Karren	unknown
Neochlamisus chamaedaphnes (Brown)	unknown
Neochlamisus eubati (Brown)	49 specimens: 13 counties, 1971–2009
Neochlamisus gibbosus (F.)	16 specimens: 7 counties, 1985–2008 (new state record)
Neochlamisus moestificus (Lacordaire)	unknown
Neochlamisus platani (Brown)	2 specimens: 2 counties, 1983–1992

The fourth species was *Pachybrachis relictus* Fall that may have been present but not confirmed. A breakdown of specimens, species, and records by collection examined is presented in Table 2.

Griburius scutellaris (F.) (Figure 1A) (new state record)

Kentucky Counties. Bullitt, Christian, Grayson, Hardin, LaRue, Lewis, Logan, Meade, Robertson, Trigg
Years. 1970 (1), 1972 (1), 1983 (1), 1985 (1), 2004 (3), 2005 (11), 2006 (32), 2007 (7), 2008 (9), 2009 (5)
Months. May (32), June (35), July (4)
Abundance. 71 specimens: 67-KYSU, 2-RJBC, 2-UKIC
Comments. The majority of specimens were recently collected in barren areas of state nature preserves managed with prescribed burning. Clark et al. (2004) reported this species from *Desmodium* (Fabaceae), *Quercus* (Fagaceae) and *Ceanothus* (Rhamnaceae).

Pachybrachis atomarius (F. E. Melsheimer) (Figure 1B)

Kentucky Counties. Christian, Nelson, Trigg
Years. 1985 (2), 2008 (38), 2009 (14)
Months. June (53), July (1)
Abundance. 55 specimens: 1-CMC, 52-KYSU, 2-RJBC
Comments. The Dury specimen was labeled as "Ky."

Table 2. The number of specimens, species and new Kentucky state records of Cryptocephalinae beetles (Coleoptera: Chrysomelidae) found in the largest leaf beetle collections from Kentucky.

Collection	Specimens	Species	Records
Kentucky State University Collection	2144	40	5
University of Kentucky Insect Collection	238	37	13
Robert J. Barney Collection	237	30	4
Charles Wright Collection	67	15	0
Brigham Young University Collection	30	13	2
Cincinnati Museum Center	29	14	2
Western Kentucky University Collection	8	6	1
Totals	2753	55	27

Pachybrachis bivittatus (Say) (Figure 1C) (new state record)

Kentucky Counties. Bracken, Pendleton, Scott, Trigg, Webster
Years. 1971 (9), 1972 (1), 1998 (1)
Months. June (8), July (2)
Abundance. 11 specimens: 1-BYUC, 10-UKIC
Comments. Normal hosts are species of *Salix* (Salicaceae).

Pachybrachis confusus Bowditch (Figure 1D) (new state record)

Kentucky Counties. Christian, Hardin, Trigg
Years. 1976 (1), 2004 (2), 2008 (15), 2009 (5)
Months. June (19), July (4)
Abundance. 23 specimens: 22-KYSU, 1-RJBC
Comments. All recently collected specimens were taken in barrens managed with prescribed burning. Minor feeding was observed in laboratory on *Chamaecrista fasciculata* (Michx.) Greene (Fabaceae) (Barney and Hall 2011).

Pachybrachis diversus Fall (Figure 1E) (new state record)

Kentucky Counties. Fulton, Hickman
Year. 1972 (2)
Months. May (1), July (1)
Abundance. 2 specimens: 2-UKIC
Comments. Normal hosts are species of *Salix* (Salicaceae).

Pachybrachis hepaticus hepaticus (F. E. Melsheimer) (Figure 1F) (new state record)

Kentucky Counties. Fayette, Hardin, LaRue, Robertson
Years. 1894 (1), 1920 (2), 2004 (1), 2005 (1), 2006 (1), 2008 (1), 2009 (2)
Months. June (7), July (1)
Abundance. 8 specimens: 6-KYSU, 2-UKIC
Comments. The specimen collected in 1894 had 'on hemp' written on the label.

Pachybrachis luridus (F.) (Figure 1G) (new state record)

Kentucky Counties. Calloway, Christian, Hardin, Trigg

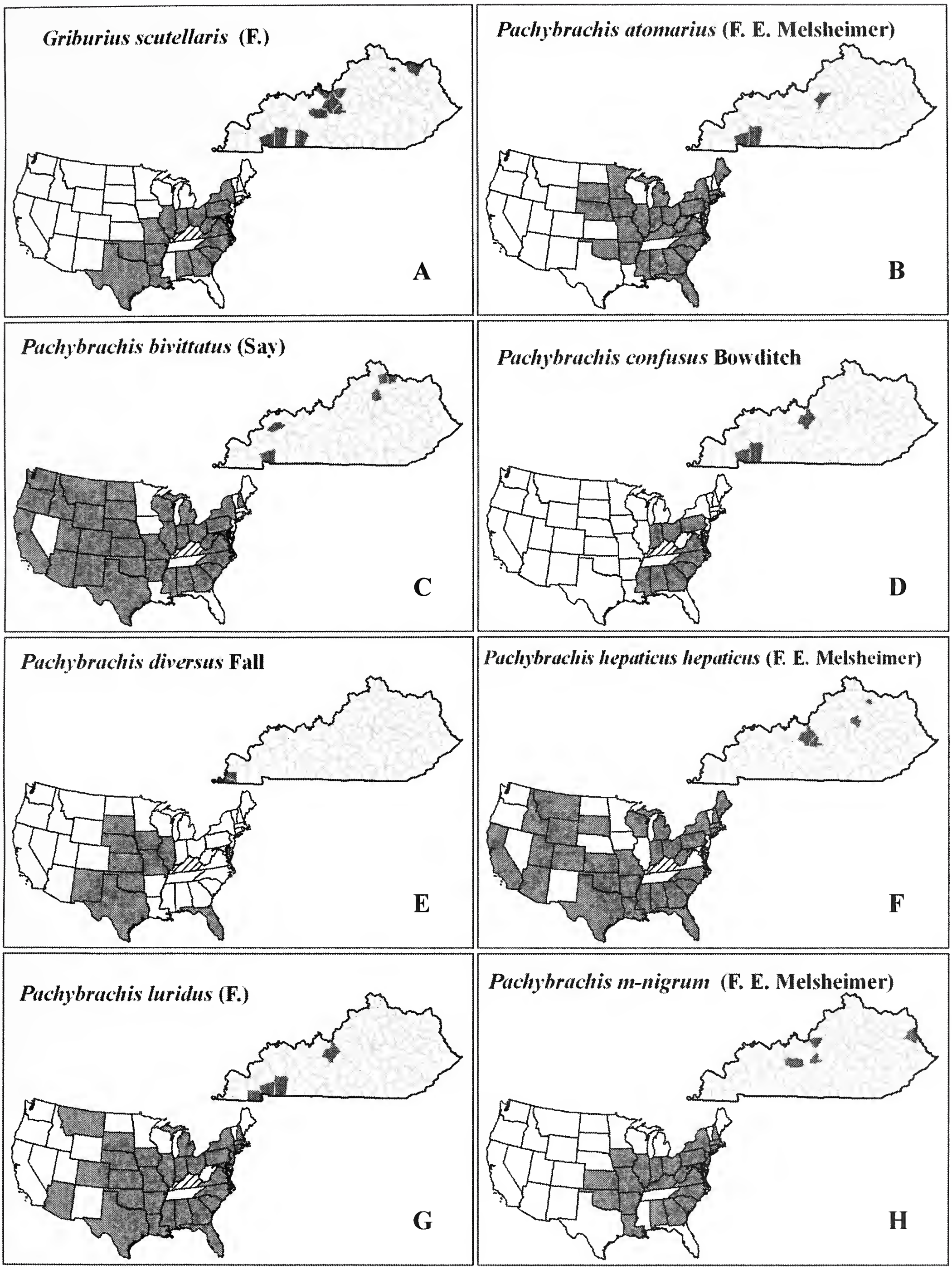

Figure 1. The known distribution of Cryptocephalinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

Years. 1970 (2), 2004 (1), 2006 (1), 2008 (3), 2009 (4)
Months. May (1), June (10)
Abundance. 11 specimens: 9-KYSU, 2-UKIC
Comments. The recently collected specimens probably were collected on *Quercus* spp. (Fagaceae).

Pachybrachis m-nigrum (F. E. Melsheimer) (Figure 1H)

Kentucky Counties. Bullitt, LaRue, Lawrence, Logan
Years. 1971 (1), 1983 (6), 2004 (11), 2005 (41), 2006 (8), 2007 (2), 2008 (4), 2009 (1)
Months. May (31), June (26), July (6), August (1)
Abundance. 74 specimens: 67-KYSU, 6-RJBC, 1-UKIC
Comments. All recently collected specimens were taken in barrens managed with prescribed burning. Several specimens were collected by sweeping *Hypericum* (Clusiaceae). Barney and Hall (2011) reported collection from and feeding on *Hypericum dolabriforme* Vent.

Pachybrachis morosus Haldeman (Figure 2A) (new state record)

Kentucky Counties. Hardin, Logan
Years. 2005 (2), 2006 (3), 2008 (3), 2009 (17)
Month. May (25)
Abundance. 25 specimens: 25-KYSU
Comments. All specimens were collected from southern red oak, *Quercus falcata* Michx., or blackjack oak, *Q. marilandica* Muenchh. (Fagaceae), at Raymond Athey Barrens State Nature Preserve and Eastview Barrens State Nature Preserve. Feeding and mating were observed in laboratory on *Q. falcata*, *Q. marilandica*, and *Q. stellata* Wangenh. (Barney and Hall 2011).

Pachybrachis nigricornis carbonarius Haldeman (Figure 2B)

Kentucky Counties. Christian, Grayson, Henry, LaRue, Lewis, Logan, Pendleton, Robertson, Trigg
Years. 1971 (1), 1983 (11), 1985 (6), 2004 (1), 2005 (16), 2006 (69), 2007 (10), 2008 (95), 2009 (77)
Months. May (100), June (178), July (8)
Abundance. 286 specimens: 268-KYSU, 17-RJBC, 1-UKIC
Comments. Barney and Hall (2009) reported this species to feed on *Desmodium* and *Lespedeza* (Fabaceae) in Kentucky.

Pachybrachis obsoletus Suffrian (Figure 2C) (new state record)

Kentucky Counties. Fulton, Scott, Trigg
Years. 1971 (1), 1972 (1), 2008 (3)
Month. July (5)
Abundance. 5 specimens: 3-KYSU, 2-UKIC
Comments. The KYSU specimens were collected from *Salix* (Salicaceae).

Pachybrachis othonus othonus (Say) (Figure 2D) (new state record)

Kentucky Counties. Carter, Grayson, Lewis, Lyon, Robertson, Trigg
Years. 1971 (2), 1983 (1), 1985 (1), 2006 (14), 2008 (8), 2009 (7)
Months. May (3), June (25), July (5)
Abundance. 33 specimens: 29-KYSU, 2-RJBC, 2-UKIC
Comments. Barney and Hall (2011) reported feeding, mating, and oviposition in the lab on *Desmodium marilandicum* (L.) (Fabaceae).

Pachybrachis peccans Suffrian (Figure 2E) (new state record)

Kentucky County. Bracken
Year. 1998 (1)
Month. July (1)
Abundance. 1 specimen: 1-BYUC
Comments. LeSage (1985) reported that larvae feed on dead or dying leaves of *Salix* (Salicaceae).

Pachybrachis pectoralis (F. E. Melsheimer) (Figure 2F) (new state record)

Kentucky Counties. Fulton, Hardin, Grayson, Logan, Robertson
Years. 1891 (1), 1971 (2), 2003 (1), 2004 (2), 2007 (1), 2008 (1), 2009 (1)
Months. June (3), July (5), September (1)
Abundance. 10 specimens: 1-CMC, 1-CWC, 5-KYSU, 3-UKIC
Comments. The Dury specimen was labeled "Ky." Clark et al (2004) reported this

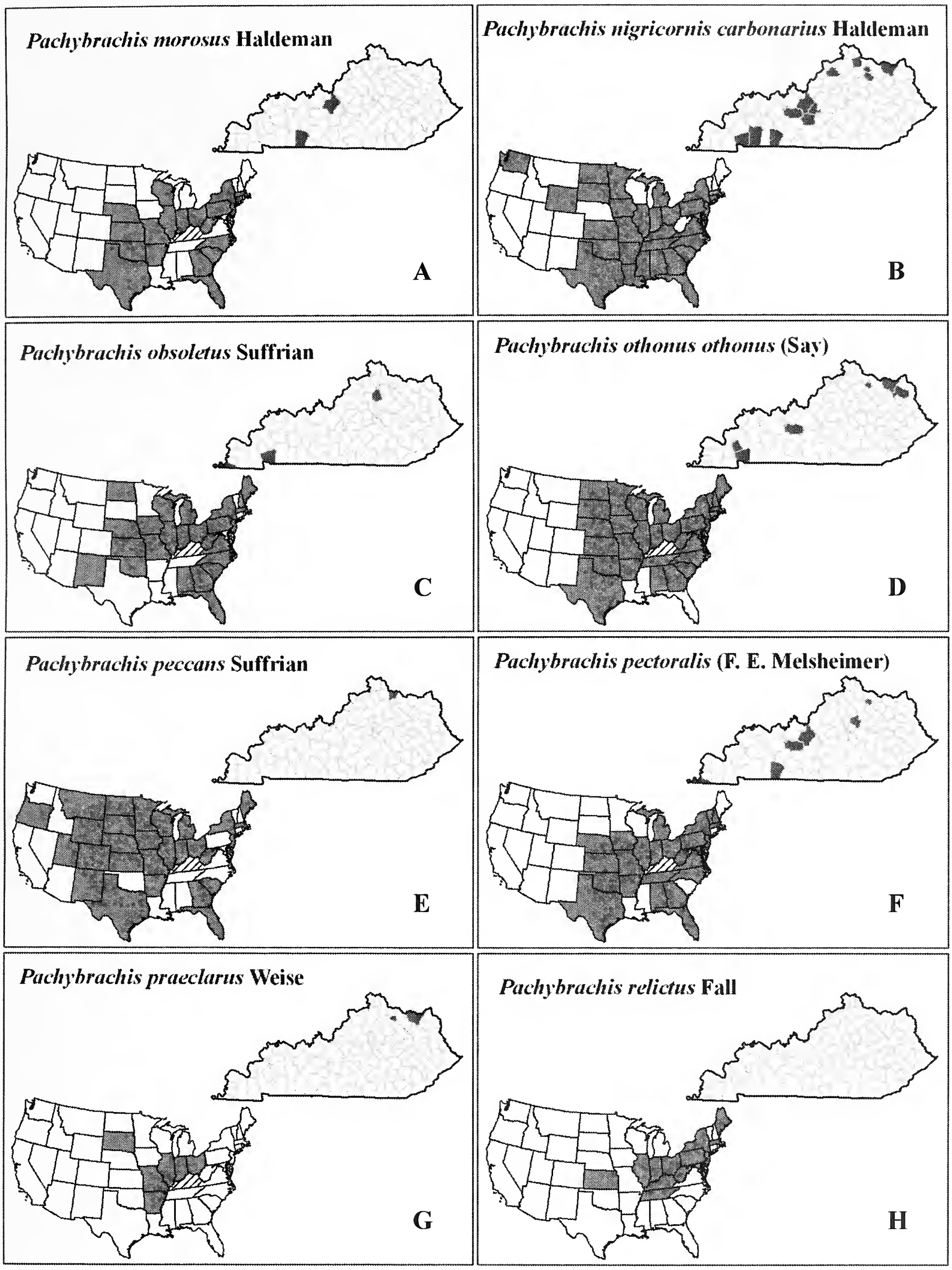

Figure 2. The known distribution of Cryptocephalinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

species as associated with *Robinia pseudoacacia* L. (Fabaceae).

Pachybrachis praeclarus Weise (Figure 2G) (new state record)

Kentucky Counties. Lewis, Robertson
Years. 2005 (1), 2006 (11), 2008 (1), 2009 (4)
Months. May (2), June (14), July (1)
Abundance. 17 specimens: 17-KYSU
Comments. This species has only been found in barrens managed with prescribed burning at Blue Licks Battlefield State Resort Park and Crooked Creek Barrens State Nature Preserve in northeast Kentucky.

Pachybrachis relictus Fall (Figure 2H)

Comments. Riley et al. (2003) listed this species from Kentucky.

Pachybrachis spumarius Suffrian (Figure 3A) (new state record)

Kentucky Counties. Allen, Breathitt, Breckinridge, Bullitt, Christian, Grayson, Hardin, Hart, Lewis, Logan, Robertson, Trigg
Years. 1972 (2), 1983 (4), 1984 (2), 1985 (3), 2004 (31), 2005 (18), 2006 (15), 2007 (9), 2008 (65), 2009 (20)
Months. June (54), July (113), August (2)
Abundance. 169 specimens: 158-KYSU, 9-RJBC, 2-UKIC
Comments. Many recently collected specimens were taken in abundance on *Rhus copallina* L. and *R. glabra* L. (Anacardiaceae). Feeding, mating, and oviposition were readily observed in the laboratory on these species. (Barney and Hall 2011).

Pachybrachis subfasciatus (J. L. LeConte) (Figure 3B)

Kentucky Counties. Hardin, Powell
Years. 2003 (1), 2009 (2)
Months. May (1), June (2)
Abundance. 3 specimens: 1-CWC, 2-KYSU
Comments. Clark et al. (2004) reported this species as associated with *Juglans nigra* L. (Juglandaceae).

Pachybrachis tridens (F. E. Melsheimer) (Figure 3C)

Kentucky Counties. unknown
Years. pre-1931 (1)
Months. unknown
Abundance. 1 specimen: 1-CMC
Comments. The Dury specimen was labeled as "Ky. near Cin. O." Clark et al. (2004) reported this species as associated with *Toxicodendron radicans* (L.) Kuntze (Anacardiaceae).

Pachybrachis trinotatus (F. E. Melsheimer) (Figure 3D) (new state record)

Kentucky Counties. Breathitt, Bullitt, Casey, Christian, Hart, LaRue, Lewis, Logan, Meade, Nelson, Trigg
Years. 1966 (1), 1972 (3), 1985 (1), 2005 (24), 2006 (12), 2008 (25), 2009 (12)
Months. June (40), July (37), August (1)
Abundance. 78 specimens: 68-KYSU, 6-RJBC, 4-UKIC
Comments. Many recently collected specimens were handpicked from *Hypericum punctatum* Lam. (Clusiaceae). Barney and Hall (2011) reported feeding, mating, and oviposition in the lab on *Hypericum punctatum*, *H. perforatum* L., and *H. dolibriforme*.

Pachybrachis viduatus (F.) (Figure 3E) (new state record)

Kentucky Counties. Hardin, Logan
Years. 2004 (2), 2005 (12), 2006 (3), 2007 (3), 2008 (5), 2009 (3)
Months. May (2), June (16), July (10)
Abundance. 28 specimens: 28-KYSU
Comments. This species has only been found in barrens managed with prescribed burning at Eastview Barrens State Nature Preserve and Raymond Athey Barrens State Nature Preserve.

Lexiphanes saponatus (F.) (Figure 3F)

Kentucky Counties. Breckinridge, Bullitt, Christian, Hardin, Jessamine, Lewis, Pulaski, Trigg
Years. 1893 (1), 1970 (1), 1972 (1), 1989 (2), 2005 (1), 2006 (1), 2008 (9), 2009 (1)
Months. June (11), July (4), August (2)
Abundance. 17 specimens: 2-BYUC, 12-KYSU, 3-UKIC
Comments. Clark et al. (2004) reported this species to be primarily associated with *Chamaedaphne calyculata* (L.) Monench (Ericaceae), but a wide assortment of other plant associations has been published.

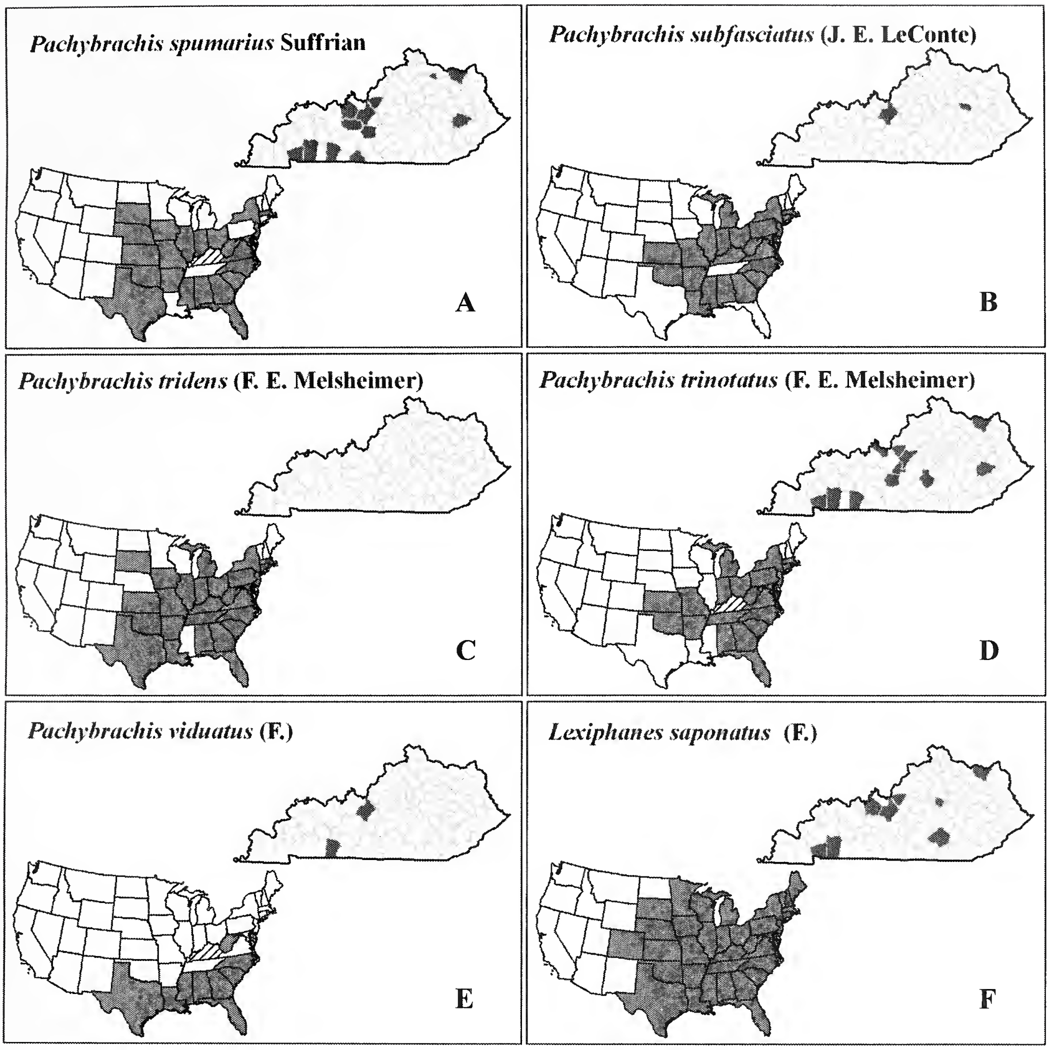

Figure 3. The known distribution of Cryptocephalinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

Bassareus clathratus (Melsheimer)
(Figure 4A)

Kentucky Counties. Barren, Breckinridge, Casey, Christian, Elliott, Fayette, Grayson, Hardin, Jessamine, Logan, Lyon, Meade, Monroe, Owsley, Russell, Trigg, Wayne

Years. 1893 (1), 1894 (1), 1952 (2), 1961 (1), 1963 (1), 1970 (1), 1971 (2), 1972 (2), 1983 (3), 1985 (4), 1987 (1), 1994 (1), 2004 (7), 2005 (15), 2006 (5), 2007 (5), 2008 (16), 2009 (2)

Months. June (29), July (38), August (2), November (1)

Abundance. 71 specimens: 2-BYUC, 1-CMC, 1-CWC, 50-KYSU, 7-RJBC, 9-UKIC, 1-WKUC

Comments. The Dury specimen was labeled from "Ky. near Cin. O." Some of the recent Kentucky specimens were sweep from winged sumac [*Rhus copallina* L.] (Anacardiaceae). Clark et al. (2004) reported this species from alder [*Alnus*] (Betulaceae), *Clethra* (Clethraceae) and *Salix nigra* Marsh. (Salicaceae).

Bassareus formosus (Melsheimer) (Figure 4B)

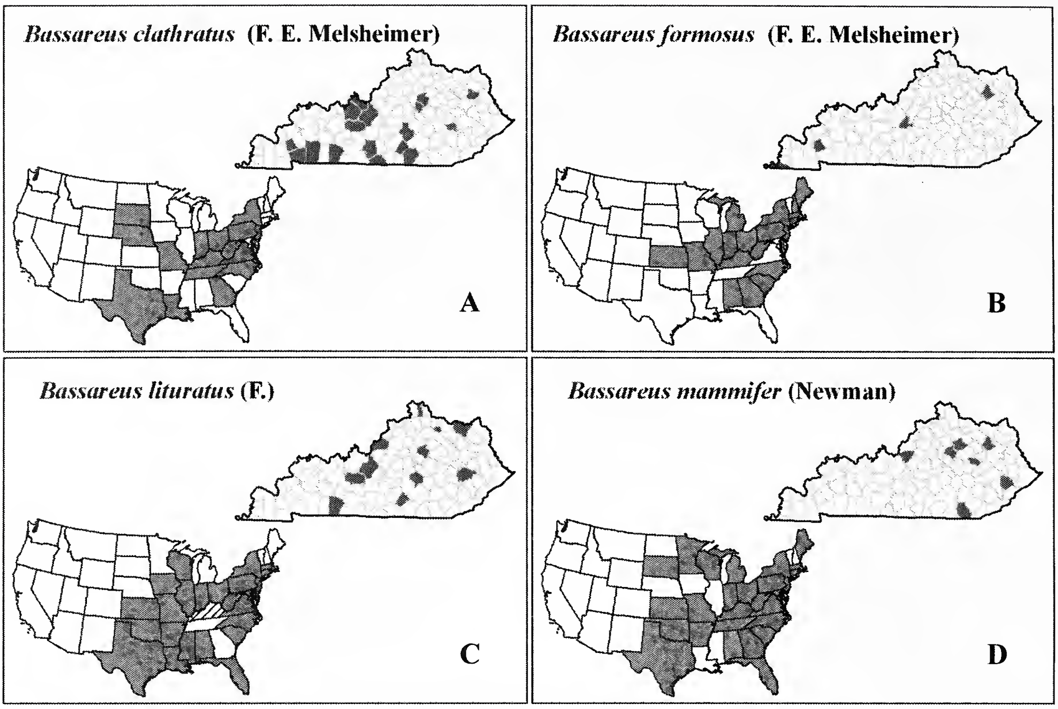

Figure 4. The known distribution of Cryptocephalinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

Kentucky Counties. Fulton, LaRue, Lyon, Rowan

Years. pre-1931 (1), 1947 (1), 1971 (3), 2006 (1), 2009 (4)

Months. May (5), June (3), July (1)

Abundance. 10 specimens: 1-BYUC, 1-CMC, 5-KYSU, 3-UKIC

Comments. The Dury specimen was labeled as "Ky. near Cin. O." Some of the recent Kentucky specimens were sweep from *Ostrya virginiana* (Mill.) K. Koch. (Betulaceae), and captive beetles fed on this plant (Barney and Hall 2011). Clark et al. (2004) reported many plant associations, including those involving *Rhus* (Anacardiaceae) and *Alnus* (Betulaceae).

Bassareus lituratus (F.) (Figure 4C) (new state record)

Kentucky Counties. Breathitt, Fayette, Grayson, Hardin, Jefferson, Kenton, Lewis, Lincoln, Logan, Robertson, Russell

Years. 1892 (1), 1945 (1), 1972 (1), 1976 (1), 1981 (1), 1983 (6), 2004 (9), 2005 (15), 2006 (36), 2007 (7), 2008 (68), 2009 (7)

Months. March (1), May (53), June (93), July (6)

Abundance. 153 specimens: 141-KYSU, 9-RJBC, 3-UKIC

Comments. Some of the recent Kentucky specimens were collected from *Lespedeza virginica* (L.) Britton (Fabaceae).

Bassareus mammifer (Newman) (Figure 4D)

Kentucky Counties. Bourbon, Bullitt, Fayette, Knott, Powell, Rowan, Whitley

Years. 1907 (4), 1912 (1), 1939 (1), 1947 (2), 1955 (1), 1971 (1), 1998 (1), 2003 (1)

Months. May (3), June (9)

Abundance. 12 specimens: 1-BYUC, 4-CMC, 2-CWC, 5-UKIC

Comments. The Dury specimens were labeled as from "Ky. near Cin. O."

Cryptocephalus badius Suffrian (Figure 5A)

Kentucky Counties. Fayette, Hickman

Years. pre-1931 (3), 1971 (3)

Months. June (1), July (1), August (1)

Abundance. 6 specimens: 3-CMC, 3-UKIC

Comments. The Dury specimens were labeled as from "Ky. near Cin. O."

Cryptocephalus calidus Suffrian (Figure 5B) (new state record)

Kentucky Counties. Grayson, Hardin
Year. 1985 (2)
Month. June (2)
Abundance. 2 specimens: 2-RJBC
Comments. These specimens were collected in railroad prairies. Clark et al. (2004) reported that this species has an association with Fabaceae.

Cryptocephalus fulguratus LeConte (Figure 5C) (new state record)

Kentucky County. Hart
Year. 2005 (1)
Month. September (1)
Abundance. 1 specimen: 1-WKUC
Comments. Clark et al. (2004) reported that this species is associated with *Quercus* (Fagaceae).

Cryptocephalus gibbicollis decrescens R. White (Figure 5D) (new state record)

Kentucky County. Barren
Year. 1892 (1)
Month. June (1)
Abundance. 1 specimen: 1-UKIC
Comments. Clark et al. (2004) reported rearing adults from larvae found on *Vaccinium* (Ericaceae). The only previous records of this subspecies are from Florida and Massachusetts.

Cryptocephalus guttulatus Olivier (Figure 5E)

Kentucky Counties. Breathitt, Fayette, Franklin, Jessamine, McCracken, Rowan, Union, Warren
Years. 1915 (1), 1945 (2), 1967 (1), 1971 (1), 1979 (1), 1983 (1), 1984 (1), 1987 (2), 1995 (1)
Months. May (3), June (3), July (3), August (1), October (1)
Abundance. 12 specimens: 1-BYUC, 1-CMC, 4-RJBC, 5-UKIC, 1-WKUC
Comments. The Dury specimen was labeled as "Ky. near Cin. O." One specimen was collected via Malaise trap.

Cryptocephalus leucomelas leucomelas Suffrian (Figure 5F)

Kentucky Counties. Crittenden, Franklin, Graves, Grayson, Jefferson, McLean, Powell, Rowan, Trigg
Years. 1954 (4), 1971 (1), 1973 (3), 1985 (1), 1994 (1), 2005 (2), 2008 (2)
Months. June (6), July (5), August (3)
Abundance. 14 specimens: 1-CWC, 4-KYSU, 1-RJBC, 8-UKIC
Comments. Several Kentucky specimens were collected directly from *Salix* (Salicaceae).

Cryptocephalus mucoreus LeConte (Figure 5G)

Kentucky Counties. Grayson, Hart, Trigg
Years. 1983 (1), 1985 (1), 2008 (1), 2009 (1)
Month. June (4)
Abundance. 4 specimens: 2-KYSU, 2-RJBC
Comments. Clark et al. (2004) reported that this species has been collected abundantly on *Rhus glabra* L. (Anacardiaceae).

Cryptocephalus mutabilis Melsheimer (Figure 5H) (new state record)

Kentucky Counties. Breathitt, Fayette, Grayson, Hardin, LaRue, Logan, Powell, Warren
Years. 1894 (1), 1916 (1), 1971 (1), 1972 (1), 2001 (1), 2004 (6), 2005 (1), 2008 (1)
Months. June (2), July (4), August (4), September (3)
Abundance. 13 specimens: 8-KYSU, 4-UKIC, 1-WKUC
Comments. Some specimens were collected via Malaise trap.

Cryptocephalus nanus F. (Figure 6A)

Kentucky Counties. Calloway, Grayson, Pulaski, Trigg
Years. 1970 (1), 1983 (1), 2008 (2), 2009 (1)
Months. June (4), July (1)
Abundance. 5 specimens: 3-KYSU, 1-RJBC, 1-UKIC
Comments. Several Kentucky specimens were collected directly from *Salix* (Salicaceae).

Cryptocephalus notatus F. (Figure 6B) (new state record)

Kentucky Counties. Breathitt, Carter, Fayette, Grayson, Hardin, Jessamine, Logan, Madison, McCreary, Mercer, Trigg
Years. 1939 (1), 1941 (1), 1942 (4), 1943 (1), 1946 (1), 1950 (1), 1971 (1), 1983 (6), 1985 (1), 2005 (1), 2006 (1), 2008 (2), 2009 (5)

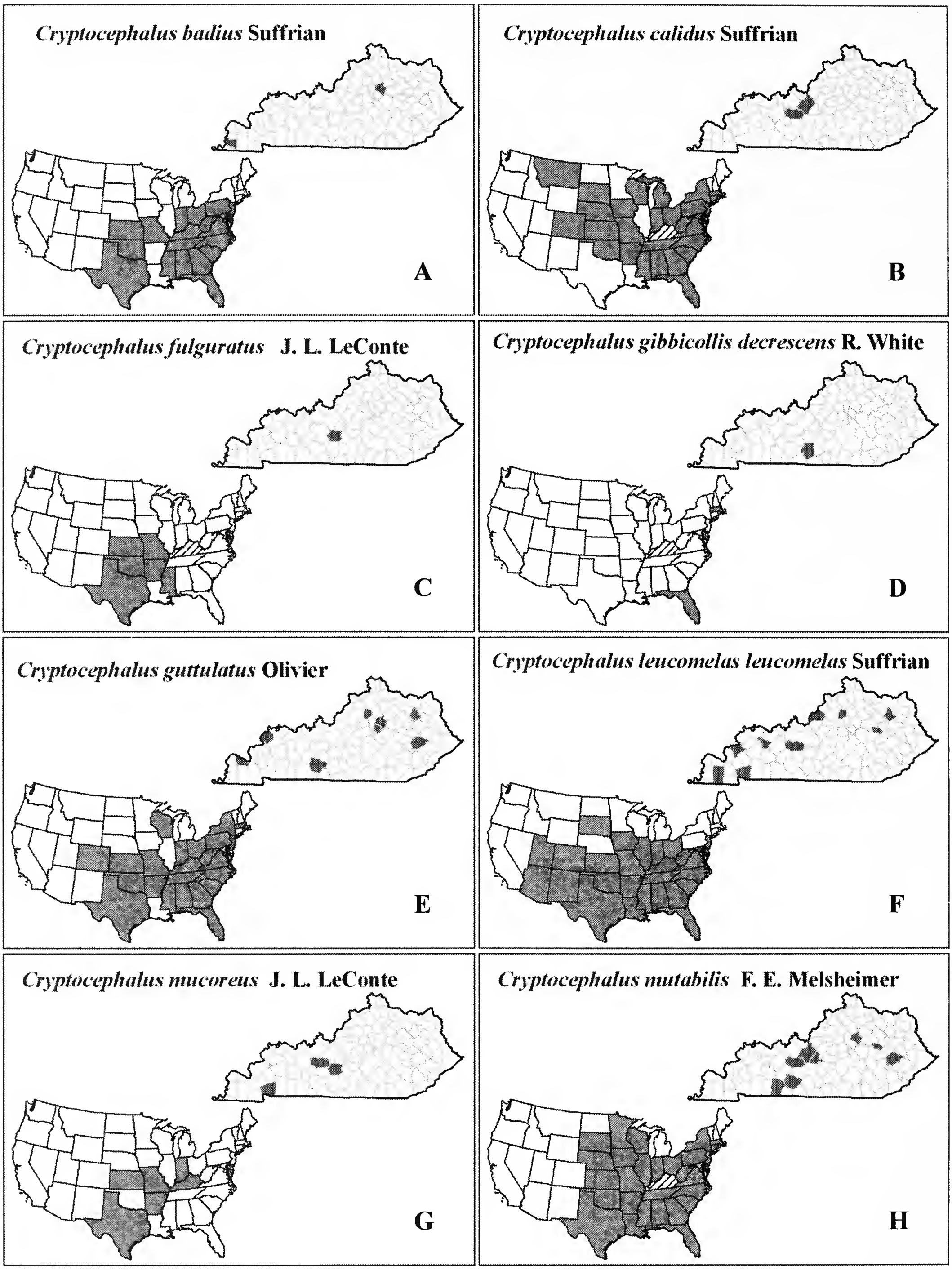

Figure 5. The known distribution of Cryptocephalinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

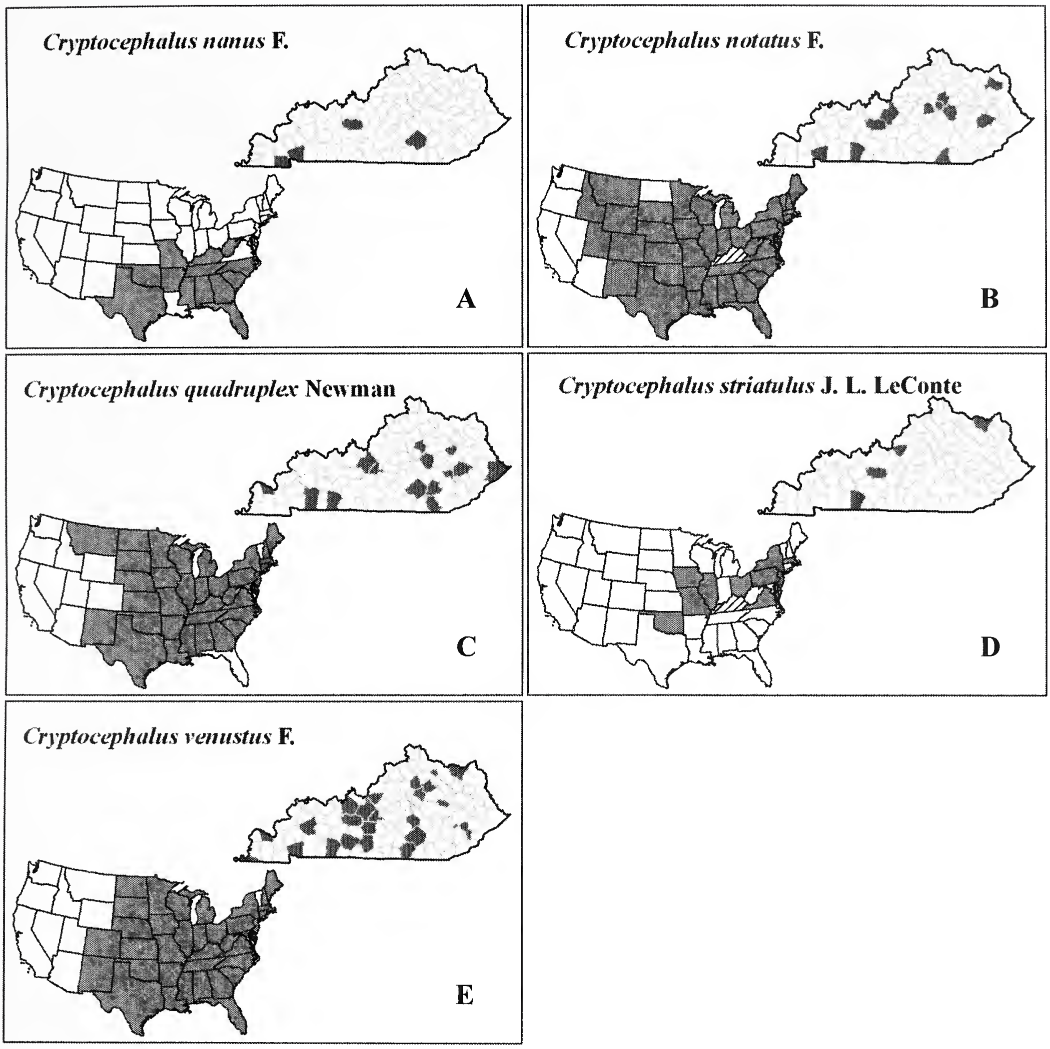

Figure 6. The known distribution of Cryptocephalinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

Months. May (13), June (13)

Abundance. 27 specimens: 1-CMC, 9-KYSU, 7-RJBC, 10-UKIC

Comments. The Dury specimen was labeled as "Ky. near Cin. O." Many Kentucky specimens were collected directly from *Salix* (Salicaceae).

Cryptocephalus quadruplex Newman
(Figure 6C)

Kentucky Counties. Breathitt, Christian, Fayette, Hardin, LaRue, Laurel, Logan, Madison, McCracken, Menifee, Owsley, Pike, Pulaski, Whitley

Years. 1891 (1), 1916 (1), 1945 (2), 1971 (2), 1972 (1), 1976 (1), 1983 (1), 1992 (1), 1994 (1), 1995 (2), 1999 (1), 2004 (1), 2005 (1), 2006 (3), 2008 (2), 2009 (3)

Months. May (6), June (17), July (1)

Abundance. 24 specimens: 1-BYUC, 4-CWC, 10-KYSU, 2-RJBC, 7-UKIC

Comments. Some specimens were collected via Malaise trap.

Cryptocephalus striatulus LeConte
(Figure 6D) (new state record)

Kentucky Counties. Bullitt, Grayson, Lewis, Logan

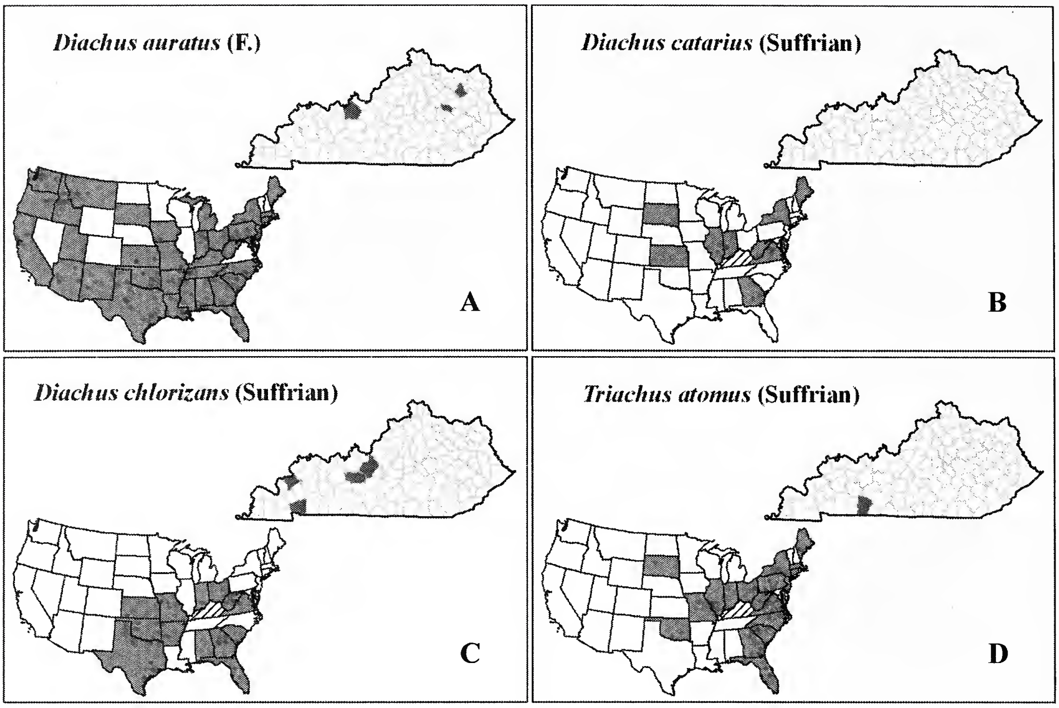

Figure 7. The known distribution of Cryptocephalinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

Years. 2005 (15), 2006 (16), 2007 (2), 2008 (17), 2009 (4)
Months. May (48), June (6)
Abundance. 54 specimens: 54-KYSU
Comments. All specimens were recently collected in barren areas of state nature preserves managed with prescribed burning.

Cryptocephalus venustus F. (Figure 6E)

Kentucky Counties. Barren, Bourbon, Breckinridge, Bullitt, Christian, Fayette, Fulton, Grayson, Hardin, Hart, Hopkins, Lewis, Logan, McCracken, Nelson, Perry, Powell, Pulaski, Robertson, Scott, Trigg, Warren, Wayne
Years. 1891 (2), 1892 (3), 1894 (2), 1913 (2), 1917 (1), 1920 (9), 1925 (1), 1938 (1), 1971 (2), 1972 (6), 1976 (1), 1983 (11), 1985 (31), 2004 (5), 2005 (93), 2006 (68), 2007 (17), 2008 (62), 2009 (21)
Months. May (2), June (192), July (134), August (9), September (1)
Abundance. 339 specimens: 1-CMC, 264-KYSU, 42-RJBC, 30-UKIC, 2-WKUC
Comments. The Dury specimen was labeled as "Ky. near Cin. O." Some specimens were collected via Malaise trap.

Diachus auratus (F.) (Figure 7A)

Kentucky Counties. Breckinridge, Powell, Rowan
Years. pre-1931 (3), 1972 (1), 1984 (1), 1995 (1)
Months. July (2), August (1)
Abundance. 6 specimens: 2-BYUC, 3-CMC, 1-UKIC
Comments. The Dury specimens were labeled as from "Ky."

Diachus catarius (Suffrian) (Figure 7B) (new state record)

Kentucky County. unknown
Year. pre-1931 (4)
Month. unknown
Abundance. 4 specimens: 4-CMC
Comments. The Dury specimen was labeled as "Ky." and "Horn" and were presumably from the collection of George Henry Horn.

Diachus chlorizans (Suffrian) (Figure 7C) (new state record)

Kentucky Counties. Crittenden, Grayson, Hardin, Trigg

Years. 1972 (1), 1983 (1), 2004 (16), 2005 (7), 2006 (1), 2007 (1), 2008 (2), 2009 (5)
Months. May (1), June (5), July (27), August (1)
Abundance. 34 specimens: 32-KYSU, 1-RJBC, 1-UKIC
Comments. Most Kentucky specimens were recently collected directly from *Rhus copallina* L. (winged sumac) at Eastview Barrens State Nature Preserve and Fort Campbell.

Triachus atomus (Suffrian) (Figure 7D) (new state record)

Kentucky County. Logan
Year. 2006 (1)
Month. June (1)
Abundance. 1 specimen: 1-KYSU
Comments. The single specimen was recently collected at Raymond Athey State Nature Preserve.

Anomoea flavokansiensis Moldenke (Figure 8A)

Kentucky Counties. Barren, Bullitt, Christian, Crittenden, Fayette, Franklin, Fulton, Grayson, Henry, Hopkins, McLean, Meade, Nelson, Ohio, Oldham, Russell, Trigg, Warren
Years. 1955 (8), 1959 (5), 1962 (4), 1963 (5), 1971 (10), 1983 (2), 1984 (1), 1987 (9), 1992 (1), 1994 (3), 1998 (1), 2002 (1), 2003 (1), 2004 (1), 2005 (2), 2007 (9), 2008 (4), 2009 (4)
Months. June (27), July (42), August (2)
Abundance. 71 specimens: 9-BYUC, 7-CWC, 20-KYSU, 3-RJBC, 32-UKIC
Comments. Several specimens were recently collected directly from *Desmanthus illinoensis* (Michx.) MacMill. ex. Robinson & Fern. (Fabaceae). Earlier label data listed *Salix*, mimosa, locust, and collection via Malaise trap.

Anomoea laticlavia laticlavia (Forster) (Figure 8B)

Kentucky Counties. Allen, Barren, Bath, Breathitt, Breckinridge, Bullitt, Calloway, Christian, Fayette, Grayson, Hardin, Jessamine, Kenton, LaRue, Lee, Lewis, Logan, Madison, McCracken, Meade, Owsley, Powell, Pulaski, Rockcastle, Scott, Trigg, Whitley, Wolfe, Woodford
Years. 1892 (3), 1895 (1), 1916 (2), 1929 (1), 1938 (3), 1939 (2), 1945 (11), 1968 (1), 1970 (1), 1971 (4), 1972 (4), 1979 (1), 1980 (1), 1983 (3), 1984 (1), 1985 (2), 1991 (2), 1992 (3), 2001 (2), 2003 (2), 2004 (7), 2005 (4), 2006 (12), 2007 (5), 2008 (23), 2009 (14)
Months. May (13), June (94), July (7), August (1)
Abundance. 115 specimens: 9-CWC, 64-KYSU, 7-RJBC, 33-UKIC, 2-WKUC
Comments. Early label data listed *Salix*, black locust, and collection via Malaise trap. Clark et al. (2004) reported that this species is normally associated with Fabaceae. Several specimens were recently collected directly from *Diospyros virginica* L. (Ebenaceae).

Coleothorpa dominicana dominicana (F.) (Figure 8C)

Kentucky Counties. Breckinridge, Bullitt, Carter, Fayette, Franklin, Grayson, Hardin, LaRue, Lewis, Lincoln, Logan, McCreary, Nelson, Pendleton, Powell, Robertson, Trigg, Whitley
Years. 1892 (1), 1895 (4), 1908 (1), 1924 (1), 1939 (1), 1942 (1), 1946 (1), 1947 (1), 1971 (5), 1983 (4), 1985 (5), 1995 (2), 2004 (1), 2005 (7), 2006 (24), 2007 (3), 2008 (18), 2009 (11)
Months. May (36), June (45), July (10)
Abundance. 92 specimens: 2-CMC, 2-CWC, 64-KYSU, 9-RJBC, 15-UKIC
Comments. The Dury specimens were labeled as from "Ky. near Cin. O." and "Ky. near bridge." Several specimens were recently collected directly from *Quercus marilandica* Münchh. (Fagaceae) and *Nyssa* sp. (Nyssaceae). Early label data listed *Quercus macrocarpa* Michx. (Fagaceae) and raspberry (*Rubus* spp.) (Rosaceae).

Coleothorpa dominicana franciscana (LeConte) (Figure 8D) (new state record)

Kentucky County. Ohio
Year. 2007 (1)
Month. May (1)
Abundance. 1 specimen: 1-BYUC

Babia quadriguttata quadriguttata (Olivier) (Figure 8E)

Kentucky Counties. Breathitt, Bullitt, Fayette, Franklin, Hardin, Knott, LaRue, Laurel, Lewis, Logan, Madison, Powell, Pulaski, Robertson, Trigg, Whitley
Years. 1942 (1), 1945 (1), 1947 (2), 1971 (2), 1972 (1), 1995 (1), 2000 (2), 2001 (2),

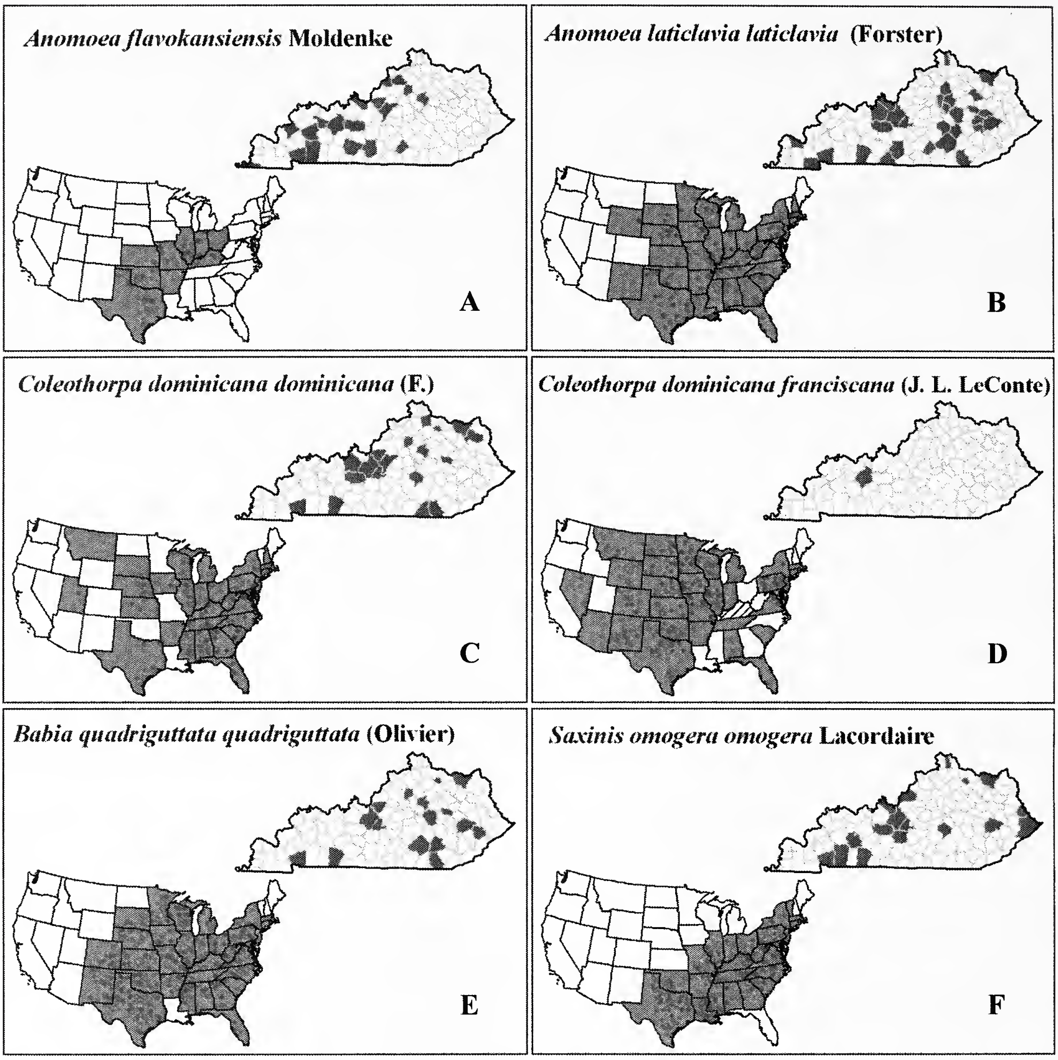

Figure 8. The known distribution of Cryptocephalinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

2003 (2), 2005 (1), 2006 (13), 2008 (9), 2009 (19)

Months. May (30), June (23), July (3)

Abundance. 58 specimens: 2-CMC, 7-CWC, 42-KYSU, 7-UKIC

Comments. The Dury specimens were labeled as from "Ky. near bridge." Several specimens were recently collected directly from *Ulmus americana* L. (Ulmaceae), *Quercus falcata* Michx. (Fagaceae), and *Carya tomentosa* (Poir.) Nutt. (Juglandaceae). Laboratory feeding was observed on *Quercus falcata*, *Q. stellata*, and *Q. marilandica* (Barney and Hall 2011).

Saxinis omogera omogera Lacordaire
(Figure 8F)

Kentucky Counties. Breathitt, Bullitt, Christian, Grayson, Hardin, Hart, Jefferson, LaRue, Lewis, Lincoln, Logan, Martin, Meade, Muhlenberg, Pike, Robertson, Trigg

Years. pre-1931 (3), 1938 (1), 1943 (3), 1971 (7), 1972 (3), 1976 (2), 1983 (5), 1985 (2), 2003 (5), 2004 (12), 2005 (49), 2006 (104), 2007 (24), 2008 (52), 2009 (2)

Months. May (91), June (167), July (13)

Abundance. 274 specimens: 3-CMC, 7-CWC, 239-KYSU, 11-RJBC, 13-UKIC

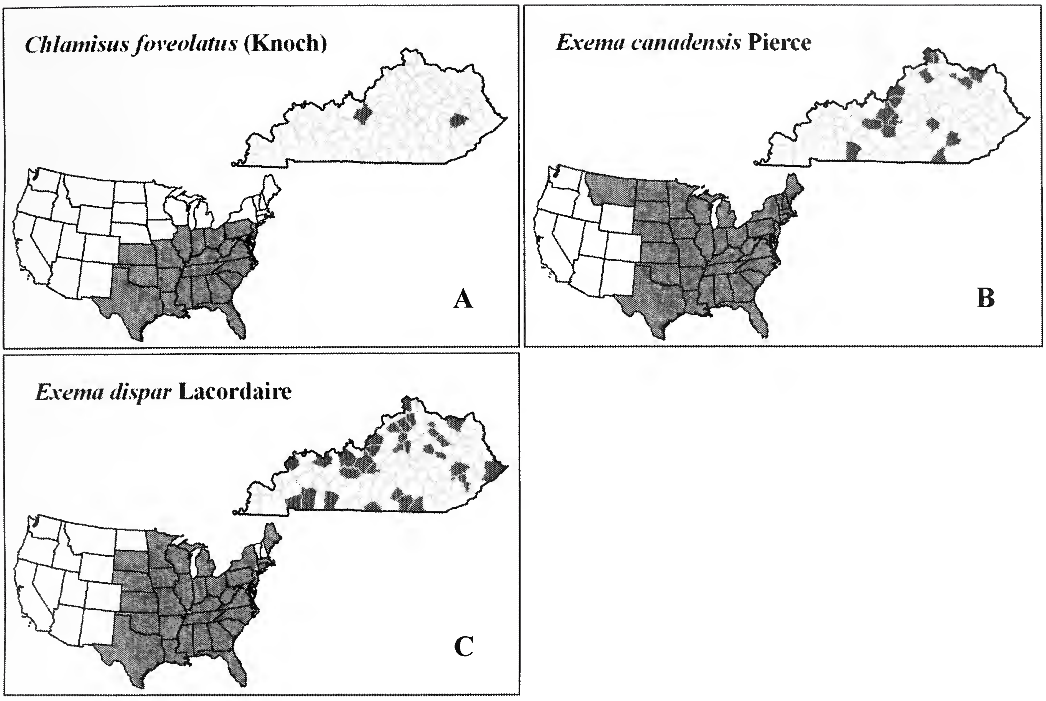

Figure 9. The known distribution of Cryptocephalinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

Comments. The Dury specimens were labeled "Ky. near bridge." Several specimens were recently collected directly from *Desmodium* (Fabaceae) and *Quercus muhlenbergii* Englem. (Fagaceae).

Chlamisus foveolatus (Knoch) (Figure 9A)

Kentucky Counties. Breathitt, Hardin
Years. 1972 (1), 2004 (1)
Months. June (1), July (1)
Abundance. 2 specimens: 1-KYSU, 1-UKIC
Comments. In his review of the tribe, Karren (1972) listed "KENTUCKY: state record, no date" for this species. The UKIC specimen was collected via Malaise trap.

Exema canadensis Pierce (Figure 9B)

Kentucky Counties. Boone, Breckinridge, Bullitt, Christian, Fleming, Grayson, Hardin, Hart, Jefferson, Kenton, LaRue, Laurel, Lewis, Lincoln, Logan, Madison, Marion, McCreary, Owen, Pulaski, Robertson, Rowan, Trigg
Years. 1971 (2), 1976 (3), 1981 (10), 1982 (2), 1983 (10), 1985 (1), 1992 (2), 1993 (1), 1995 (1), 1998 (3), 2003 (2), 2004 (15), 2005 (43), 2006 (45), 2007 (4), 2008 (48), 2009 (6)
Months. March (3), April (4), May (71), June (59), July (57), August (4)
Abundance. 198 specimens: 6-BYUC, 4-CWC, 156-KYSU, 30-RJBC, 2-UKIC
Comments. Clark et al. (2004) reported that this species is associated with Asteraceae.

Exema dispar Lacordaire (Figure 9C)

Kentucky Counties. Anderson, Bath, Boone, Breathitt, Breckinridge, Bullitt, Christian, Clark, Daviess, Franklin, Grant, Grayson, Hardin, Henry, Jefferson, LaRue, Lewis, Logan, McCreary, Monroe, Nicholas, Owen, Perry, Pike, Powell, Robertson, Russell, Trigg, Union, Wayne, Woodford
Years. 1971 (5), 1972 (1), 1981 (8), 1983 (10), 1984 (1), 1985 (1), 1993 (2), 1994 (1), 2000 (1), 2002 (1), 2003 (10), 2004 (15), 2005 (15), 2006 (40), 2007 (3), 2008 (17), 2009 (4)
Months. April (1), May (78), June (45), July (9), August (2)
Abundance. 135 specimens: 2-BYUC, 18-CWC, 85-KYSU, 24-RJBC, 6-UKIC

Comments. Clark et al. (2004) reported that this species is associated with Asteraceae.

Neochlamisus bebbianae (Brown) (Figure 10A)

Kentucky Counties. Franklin, Hardin, LaRue, Logan
Years. 2005 (1), 2006 (3), 2007 (2), 2008 (3)
Months. May (5), June (2), July (2)
Abundance. 9 specimens: 9-KYSU
Comments. All specimens were recently collected in barren areas of state nature preserves managed with prescribed burning. In his review of the tribe, Karren (1972) listed "KENTUCKY: state record, no date" for this species.

Neochlamisus bimaculatus Karren (Figure 10B)

Comments. Riley et al. (2003) listed his species as found in Kentucky.

Neochlamisus chamaedaphnes (Brown) (Figure 10C)

Comments. In his review of the tribe, Karren (1972) listed "KENTUCKY: state record, no date" for this species.

Neochlamisus eubati (Brown) (Figure 10D)

Kentucky Counties. Bullitt, Christian, Franklin, Hardin, Henry, LaRue, Laurel, Lewis, Logan, McCreary, Pulaski, Robertson, Whitley
Years. 1971 (1), 1978 (1), 1983 (4), 2004 (2), 2005 (9), 2006 (21), 2007 (2), 2008 (5), 2009 (4)
Months. April (15), May (17), June (13), July (3), September (1)
Abundance. 49 specimens: 25-KYSU, 23-RJBC, 1-UKIC
Comments. A long series of specimens was recently collected directly from a cultivated variety of thornless blackberry, *Rubus* sp. (Rosaceae). In his review of the tribe, Karren (1972) listed "KENTUCKY: Bullitt Co., 9 May" for this species.

Neochlamisus gibbosus (F.) (Figure 10E) (new state record)

Kentucky Counties. Christian, Daviess, Grayson, Hardin, Logan, Powell, Trigg
Years. 1985 (1), 1993 (2), 2004 (3), 2005 (1), 2007 (4), 2008 (5)
Months. May (4), June (6), July (5), August (1)
Abundance. 16 specimens: 2-CWC, 11-KYSU, 3-RJBC
Comments. The majority of specimens were recently collected in barren areas of state nature preserves managed with prescribed burning. Clark et al. (2004) reported that this species is associated with *Rubus* sp. (Rosaceae).

Neochlamisus moestificus (Lacordaire) (Figure 10F)

Comments. In his review of the tribe, Karren (1972) listed "KENTUCKY: state record, no date" for this species.

Neochlamisus platani (Brown) (Figure 10G)

Kentucky Counties. Butler, Menifee, Whitley
Years. 1983 (1), 1992 (1)
Month. May (2)
Abundance. 2 specimens: 1-CWC, 1-RJBC
Comments. In his review of the tribe, Karren (1972) listed "Butler Co, 16 June" for this species. Clark et al. (2004) reported that this species fed on *Plantanus* (Plantanceae).

DISCUSSION

The data presented here are the most complete representation of the cryptocephaline leaf beetles known from Kentucky. The large number of new state records documented here (27 of 59 species, or 46%), and the fact that 30 species were first collected after 1970, reflect a historical lack of leaf beetle collecting in Kentucky. A large percentage of the new records (14 of 20 species) is for species of *Pachybrachis*. The last revision of *Pachybrachis* was done by Fall (1915) almost 100 years ago.

The fact that three species of *Neochlamisus* were cited in the literature but not recovered in this study may reflect how difficult species identification is in this genus. This is due to the similarity among species, as well as to the variability within species. The situation is further complicated by the possibility of as yet undescribed species, very similar to those that are currently being recognized. This is especially so with regards to *N. bebbianae*.

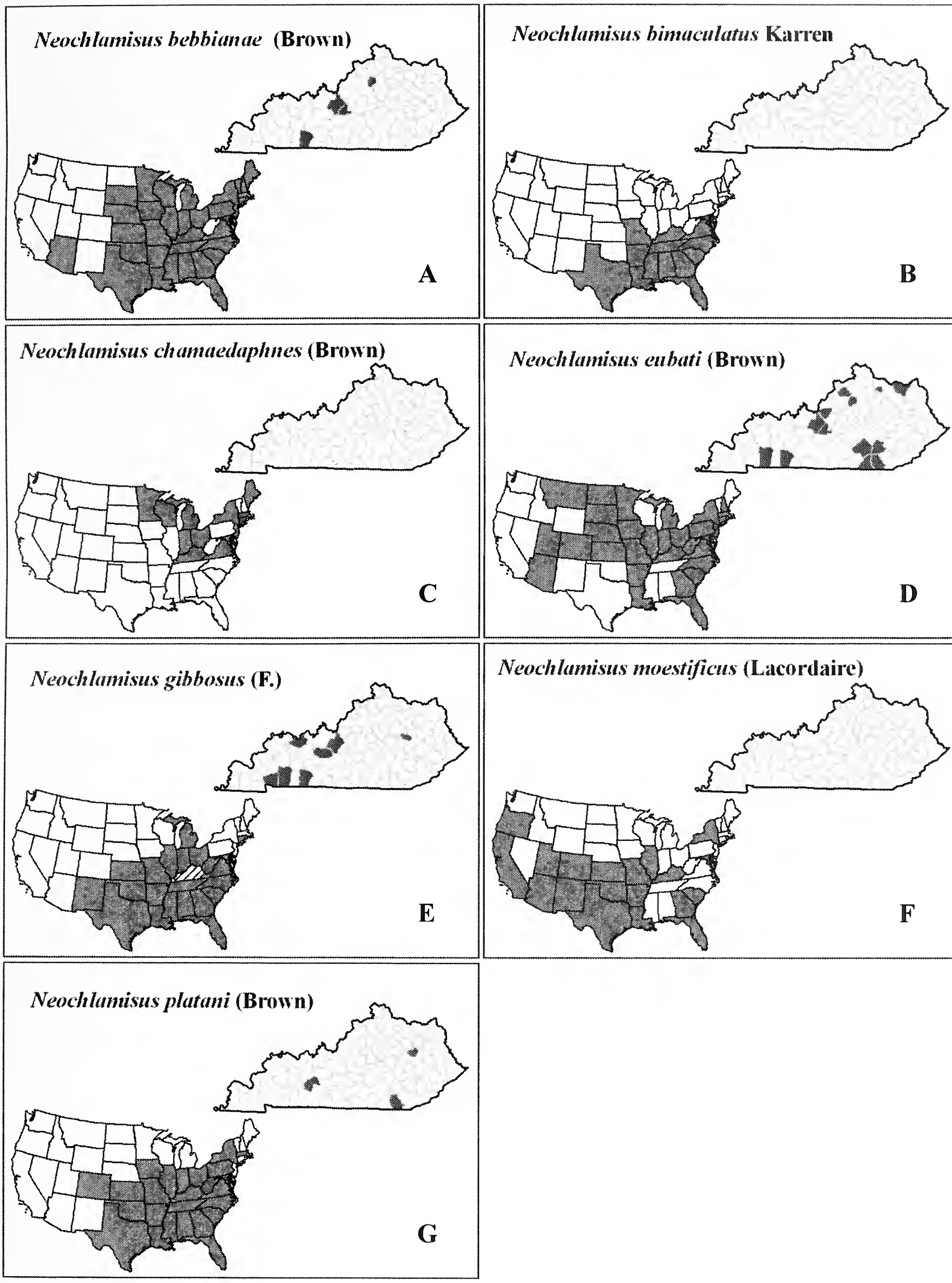

Figure 10. The known distribution of Cryptocephalinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

When Brown (1943) named this species, he also described *N. alni* (Brown). A few years later (Brown 1946), he described *N. tecta* (Brown). Subsequently, in a taxonomic revision of the genus, Karren (1972) regarded all three of these names to be synonymous with each other. Notwithstanding this proposed synonymy, LeSage (1984a) reinstated *N. alni* as a valid species. The recent investigations of Adams and Funk (1997), Funk (1998, 1999), and Funk et al. (2002) suggest that *N. bebbianae*, as currently recognized, is actually a complex of several sibling species.

CONCLUSIONS

This is the final paper in a series intended to present a synopsis of the historical collection data on Kentucky leaf beetles and augment these with new information from recent monitoring. A total of 283 species were found in the 12,910 specimens examined and re-identified, and 132 were new state records for Kentucky. Prior to this study, Riley et al. (2003) reported Kentucky to have the sixth most depauperate leaf beetle fauna in the lower 48 states. However, the results of this study, with 47% of the species found being new state records, demonstrate the historical lack of collecting done in Kentucky.

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Leaf Beetle (Coleoptera: Chrysomelidae) Biodiversity within Isolated Remnant Grasslands in Kentucky State Nature Preserves

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ABSTRACT

Leaf beetle collection data from five Kentucky State Nature Preserves are summarized over a four-year period (2005 to 2008) encompassing a total of 57 collection events. Our primary objective was to survey leaf beetle populations found within the five preserves. We also wanted to assess impacts of prescribed fire management within these habitats on leaf beetles. We used means ANOVA procedures, species richness estimators, NMS ordinations, and contingency tables analyses. There were clear differences between the five preserves, with Raymond Athey State Nature Preserve (Logan Co.) being the most diverse (87 species) and having the greatest number of rare species (30). Ordination analyses revealed very minimal impacts of prescribed burns on leaf beetle composition in the four preserves where it is used as a management practice. Overall, leaf beetle composition appeared linked with Nature Preserves sampling/management units across years, overriding any year to year differences due to weather or other influences. The only significant year to year difference within a preserve occurred at Blue Licks State Park Nature Preserve, which had a lower number of beetles in 2007, possibly due to drought that summer. In total, we found 143 species, with 9 species unique to only one preserve (four of the five preserves contained unique species). These results demonstrate the importance of protected areas such as state nature preserves as refugia not only for known threatened or endangered plants and animals, but also for associated biota in little-studied groups, such as leaf beetles.

KEY WORDS: Coleoptera, Chrysomelidae, diversity, grasslands, Kentucky, leaf beetle, preserves

INTRODUCTION

Nature preserves in the United States are typically protected due to the presence of rare plants or animals, or high biological diversity compared to surrounding areas. The primary purpose of the Kentucky State Nature Preserves Commission (KSNPC) is to preserve populations of rare native species and community types which serve as "the best-protected repository for Kentucky's biological diversity" (KSNPC 2009, p. 30). Several state nature preserves in Kentucky contain grass-dominated communities, which are believed to have covered 6–10% of the state at European settlement, but now remain in only scattered remnants (Jones 2005). These preserves include so-called barrens and glades (Evans 1991) and/or xeric limestone prairies (Lawless et al. 2006), which contain a number of species of concern listed by KSNPC, as well as two federally-listed plant species. Historically, grassland communities in Kentucky relied on periodic fires and grazing of large mammals to prevent succession to forest (KSNPC 2009). Prescribed burning and herbicides are often used as management tools to control woody plants and restore formerly cultivated areas typically dominated by tall fescue. The KSNPC often configures its management units to divide a barren or glade into two or more units on the theory that the untreated portion can serve as a refuge and reservoir for the recolonization of the burned portion (J. Bender, KSNPC pers. comm. 19 January 2010). Management units vary greatly in size, dependent primarily in the overall size of a given glade or barren.

The flora of Kentucky is relatively well known and estimated to be comprised of 2030 species of vascular plants, 386 (19%) of which are listed as threatened by the KSNPC (KSNPC 2009). Comparatively speaking, the insect fauna is much more species-rich with estimates of 10,000 (UK Entomology 2008) to 15,000 (KSNPC 2009) species in the state, however only 74 species of insects (≤0.74%) are listed as threatened by the KSNPC.

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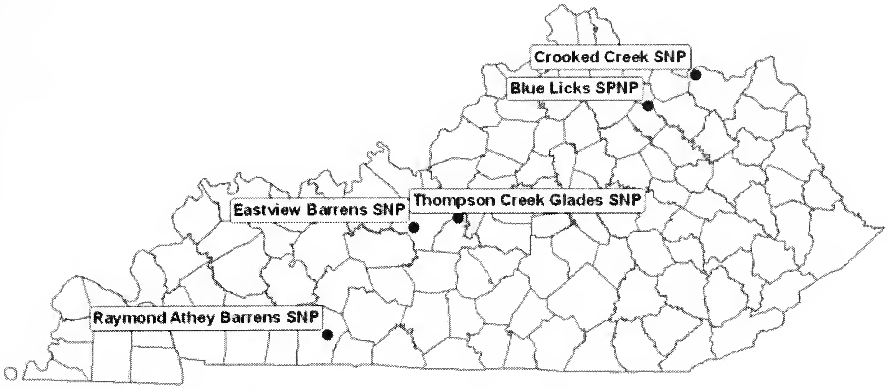

Figure 1. Location of five state nature preserves (SNPs) within Kentucky, U.S.A. included in leaf beetle biodiversity assessment.

Clearly this low number is more a reflection of the lack of understanding of these populations than their actual situation. The relatively well studied Kentucky cave beetles (Coleoptera: Carabidae: Trechinae) (which even Charles Darwin (1859) mentioned twice), represent 27 (36.5%) of the 74 listed insect species (KSNPC 2005). Given the relative smallness of this group of insects, it seems likely there are many more insects that would be considered threatened if they were better studied. Leaf beetles (Coleoptera: Chrysomelidae) may represent one such group. Although they are a diverse and conspicuous phytophagous insect family (Riley et al. 2002), occurring in habitats ranging from conventional agricultural fields to prairie remnants, many of the smaller species have been neglected due to difficulty in taxonomy. According to Riley et al. (2003), 158 species of leaf beetles were documented from Kentucky, while 575 species have been found in at least one of the seven states contiguous to Kentucky. In an effort to document the richness and distribution of chrysomelids across the Commonwealth, the Kentucky Leaf Beetle Biodiversity Project was initiated at Kentucky State University. The project's focus was on extensive collecting in many grass-dominated communities, such as barrens and glades, which are known for possessing uncommon plant species and plant communities (Jones 2005).

Preliminary collecting began in 2004 at several nature preserves across the state, and five sites were chosen for extensive monitoring from 2005 to 2008: Raymond Athey Barrens State Nature Preserve (Logan County) in western Kentucky, Crooked Creek State Nature Preserve (Lewis County) and Blue Licks State Park Nature Preserve (Robertson County) in northeastern Kentucky, and Thompson Creek Glades State Nature Preserve (LaRue County), and Eastview Barrens State Nature Preserve (Hardin County) in central Kentucky (Figure 1). Our primary objective was to compare the leaf beetle populations of the five preserves based on leaf beetle abundance and diversity. Our secondary objectives were to assess impacts of prescribed fire management within these five habitats on leaf beetles, and to assess variability in leaf beetle abundance year to year.

MATERIALS AND METHODS

Site Descriptions and Management

The five preserves in this study are managed by KSNPC with the goals of preserving and enhancing known populations of rare plants or animals, discouraging non-natives, and encouraging recruitment of native grassland species (J. Bender, KSNPC pers. comm. 19 January 2010). Of the five preserves, three include both remnant high quality grassland communities as well as areas with recent use (prior to KSNPC purchase) as pasture. Due to their proximity to high quality glades or barrens, the KSNPC manages recent pastures (which we refer to as "restorations") through the use of herbicide, prescribed fire, and physical removal of woody stems. Recruitment of native plant species occurs via rootstock, the seedbank, and seed rain; seeds are not introduced to any management units. Remnant areas are managed with the same practices, although herbicide use is more limited—typically to resprouts of woody species following prescribed burns (whereas it may be more broadly applied in restoration units depending on the cover of invasive species).

Raymond Athey Barrens State Nature Preserve (Athey SNP) is a 63-ha preserve with limestone barrens (Evans 1991) of open-grown post (*Quercus stellata* Wangenh) and black jack (*Q. marilandica* Münchh) oaks, with thin soils and bedrock at or near the surface (KSNPC 2007). Originally dedicated in 1990, nine rare species of plants are known to inhabit Athey SNP, which is accessible by written permission only. We collected leaf beetles in four barrens divided into seven management units, including both high quality remnant areas and restorations, comprising a total of 5.1 ha. During the study period six of the seven management units were burned.

Crooked Creek State Nature Preserve started as a 24-ha tract in 1999 that has expanded to include 161 ha of unique oak barrens and oak-hickory forest (KSNPC 2007). Prairie species such as big bluestem (*Andropogon gerardii* Vitman) and prairie dock (*Silphium terebinthinaceum* Jacq var. *luciae-brauniae* Steyermark) occur in barren areas. Eleven rare species of plants are listed for Crooked Creek, and it is accessible by written permission only. Although included in an examination of 18 xeric limestone prairies in Kentucky (Lawless 2005), Crooked Creek SNP separated from all other sites in ordination (plant composition was different from all other sites) and was simply labeled as a glade by Rhoades et al. (2005). We collected leaf beetles in six management units, including both remnants and restorations, totaling 3.4 ha. One unit was burned during the study.

Blue Licks State Park Nature Preserve (Blue Licks SPNP) was dedicated in 1981 and consists of 21 ha within Blue Licks Battlefield State Resort Park. The preserve was established to protect a near-endemic federally endangered plant, Short's Goldenrod (*Solidago shortii* Torr. & A. Gray) (KSNPC 2007). We collected leaf beetles in two management units totaling 1.3 ha: a glade containing part of the original pre-settlement buffalo trace and a stand of Short's goldenrod and a restoration site 0.5 miles distant across a two lane highway. Both management units are managed with periodic prescribed fire, and each was burned once during the study period.

Thompson Creek Glades State Nature Preserve (Thompson Creek SNP) has been described as a xeric limestone prairie (Lawless 2005), a calcareous glade (Lyon 2004), and a limestone slope glade (Evans 1991). It contains several hill glades (south and west-facing) on thin-bedded Salem limestone, characterized by shallow, rocky soils (KSNPC 2007). The original 26-ha tract was acquired with assistance from The Nature Conservancy in 1992 and its size has increased to a total of 69 ha. Glade openings are maintained from encroaching woody vegetation via selective cutting but not burning. Four rare species of plants are listed for Thompson Creek SNP, which is accessible by written permission only. We collected leaf beetles in four small isolated glades comprising a total of 1.3 ha.

The 49-ha Eastview Barrens State Nature Preserve (Eastview SNP) was dedicated in 1997 and includes sandstone barrens and sandstone prairie (Evans 1991). Twelve rare species of plants are listed for Eastview SNP, which is not open to the public. Prescribed fire is used throughout this preserve to maintain its grassland communities. We collected leaf beetles in three barrens divided into seven management units comprising a total of 1.6 ha. Sampling units did not completely correspond to the seven separate management units in all four years, so we combined collection data to represent the three barrens for the preserve-wide NMS ordination (see Statistical Analyses below). Parts of all three barrens were burned during the study period.

Overall Sampling Methodology

We sampled leaf beetles in selected grass-dominated habitats in each preserve during the months of May, June and July from 2005 to 2008. Each preserve was sampled 10–13 times total during the four years. A collecting visit consisted of the second author randomly walking across a management unit while sweeping the vegetation with a 15″ diameter

Table 1. Total number of specimens and species (with those considered rare, state records, and only found in that preserve-"unique locale" separated) of leaf beetles (Coleoptera: Chrysomelidae) found in five state nature preserves during 2005–2008 (n = number of sampling dates in May–July). Means with different letters in the last column are significantly different ($P < 0.05$, Tukey-Kramer HSD).

	n	Total specimens	Total species	Rare species	State records	Unique locale	Mean species per sampling date
Athey SNP	12	1263	87	30	10	5	30.3 a
Crooked Creek SNP	11	671	70	13	3	0	19.8 b
Blue Licks SPNP	10	229	45	6	1	1	10.9 c
Thompson Creek SNP	12	363	65	22	5	1	15.2 bc
Eastview SNP	13	770	72	20	4	2	18.1 bc
Total		3296	143	50	23	9	

sweep net. Periodically the net was carefully opened and the leaf beetles were directed into a vial containing 70% EtOH. All other taxa were released unharmed. All vials were returned to the laboratory where specimens were pinned, labeled and identified by the second author. Voucher specimens are housed in the Kentucky State University Beetle Collection (KYSU), Frankfort, Kentucky.

Statistical Analyses

Mean species richness and specimen number were compared using means ANOVA procedures and Tukey-Kramer HSD means comparisons (JMP 7.0.2, SAS Institute, Cary, NC), with each sampling date constituting a sample. These included comparisons within preserves between all years sampling took place, as well as between preserves for 2005–2008. Species rarefaction curves were created for each preserve using EstimatesS (Colwell 2006). We chose to report Chao 1 curves based on Hortal et al. (2006). They found this estimator to be insensitive to changes in sample grain size, and although all of our samples are at the preserve level, the area encompassed by each is quite different.

We also quantified the number of new state records and rare species found within each preserve. Each species was characterized as abundant, frequent, infrequent, local or rare as described by Hall and Barney (2010). A species was characterized as a new state record for Kentucky if it was not listed by Riley et al. (2003) for Kentucky and had not been found in the historical review of all collections known to contain Kentucky specimens (Barney et al. 2007, 2008a, 2008b, 2009a, 2009b).We performed a contingency tables analysis (JMP 7.0.2, SAS Institute, Cary, NC) to detect significant differences in the proportions of beetles from different abundance categories between years for each site and between the five different sites.

NMS ordinations (PC-ORD 4.41, MjM Software, Glenedon Beach, OR) were used to display leaf beetle composition within preserves by management unit and year. Only management units sampled all four years in a preserve were included in the ordination. Given the large variation in specimen number and management unit size, we adjusted the data to provide the most meaningful ordination results. We first took the sum of specimens for each species per management unit per year, divided that by the number of sampling visits, and then divided that by the area (ha) contained within the management unit (as determined using ArcGIS 9.3 and 2004 FSA aerial photos). This provided us with a mean specimen number per visit per ha for each management unit, and these data made up the main data matrix for each preserve. Sorenson distance measure was chosen and a Monte Carlo test was performed to provide a test statistic for final stress obtained by NMS versus that obtained with randomized versions of the data. Units that had been burned in a given sampling year were symbolized as such in the ordination plot. For Eastview SNP, we performed separate ordinations for the preserve across all years (with management units combined into the three barrens), and for one barren alone (with two management units) from 2006–2008. We performed the separate analysis on the 'middle' barren as it was unique in having uniform topography, geology, and soils (as determined with SSURGO soils maps, 24 K Topo maps, and 24 K Geologic Maps in

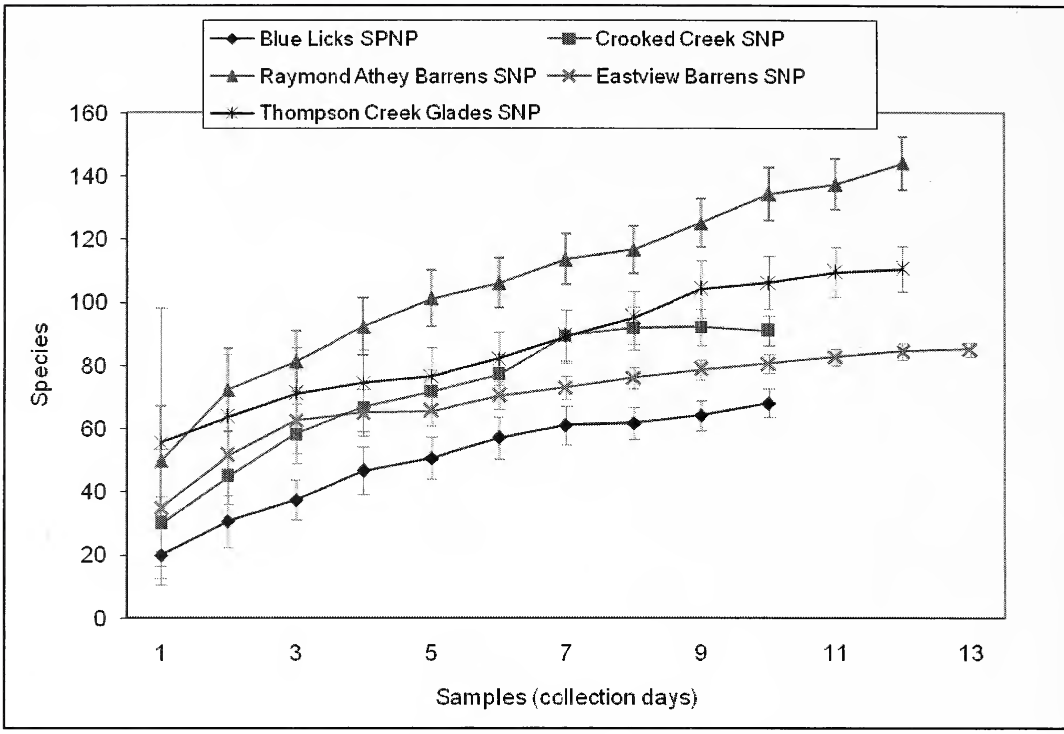

Figure 2. Chao 1 species rarefaction curves of five state nature preserves in Kentucky, created using all sampling dates (x-axis) between 2005–2008. Numbers on the y-axis are mean species richness, with bars being standard error of the mean.

ArcGIS 9.3). In 2005, this barren was collectively sampled, whereas in the following years it was sampled in its two different management units. KSNPC performed a prescribed burn on half of the barren (unit N3E) in 2007, which allowed for an analysis of prescribed fire effects on leaf beetle composition (that wasn't possible in the preserve wide analysis because collection data from the barren as a whole was combined).

RESULTS

A total of 3296 specimens representing 143 species of leaf beetles were collected during this four-year study (Table 1, see Appendix for complete inventory list). The greatest number of specimens and species richness was found at Raymond Athey Barrens SNP. The mean number of 30.3 species recovered per sampling date at Athey SNP was significantly greater than that collected at the other preserves ($P < 0.001$, Table 1). Chao 1 species rarefaction curves (Figure 2) reflected the same pattern with Raymond Athey having the greatest species richness, Blue Licks having the lowest, and the other three preserves falling intermediate between these two.

Table 2. Mean number of species of leaf beetles (Coleoptera: Chrysomelidae) per sampling date within nature preserves between four collection years. Means with different letters within a row are significantly different ($P < 0.05$, Tukey-Kramer HSD).

	2005	2006	2007	2008
Athey SNP	30.8	36.0	27.5	25.7
Crooked Creek SNP	20.3	27.7	10.0	17.0
Blue Licks SPNP	10.7b	12.3ab	4.5c	15.5a
Thompson Creek SNP	16.2	17.7	6.5	17.5
Eastview SNP	11.6	19.7	23.7	23.5

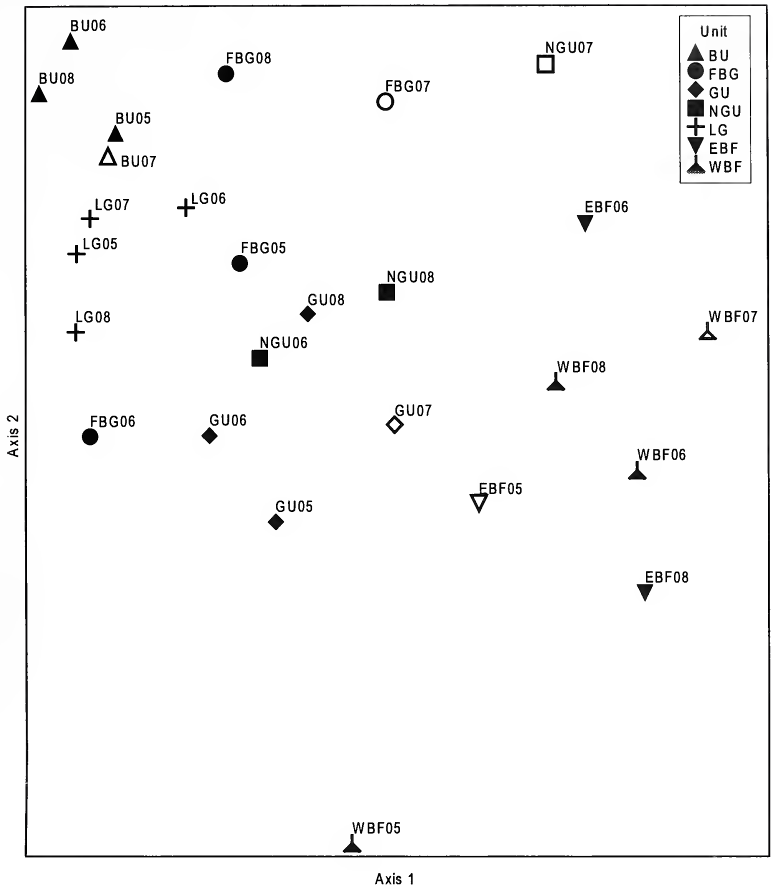

Figure 3. NMS ordination of leaf beetle collection data 2005–2008 (indicated by numbers at end of each label) at Raymond Athey Barrens SNP in Kentucky. Symbol types vary for different management units (labeled with letters), and hollow symbols indicate years in which a unit was burned late winter/early spring (prior to sampling).

The mean number of species per sampling date between years for each preserve did not change significantly except for Blue Licks SPNP (Table 2). Mean species in 2007 were significantly lower there, perhaps due to drought that year, as the entire state was under moderate to severe drought (based on Palmer Drought Severity Index) for all weeks of June and July (Kentucky DOW 2008). However, given that all preserves didn't display a consistent drop in species means, we are unable to pinpoint this as the reason for the drop (even ignoring statistical differences, 2007 mean was lowest for only three of the five). Overall, species means are quite variable from year to year within a given preserve (i.e., Thompson Creek SNP, ranging from 6.5 to 17.7). The absence of significant differences, despite wide ranges in means, demonstrates this variability as well (not only between years but between sampling dates as well). Contingency analyses revealed no significant differences for each preserve between years (data not shown) or between the five preserves over the four year period (Pearson χ^2 = 16.2, P = 0.698, data not shown). While there were clearly substantial differences in the numbers of species present at preserves, all had some species in all five abundance categories.

NMS ordinations reached two-dimensional solutions for all preserves except Blue Licks, which resulted in a one-dimensional solution (Figures 3–7). At Athey SNP (Figure 3), the restoration units (WBF and EBF) appear generally separated from the other (remnant) units. No clear separation of burned units appears in either the remnant or restoration

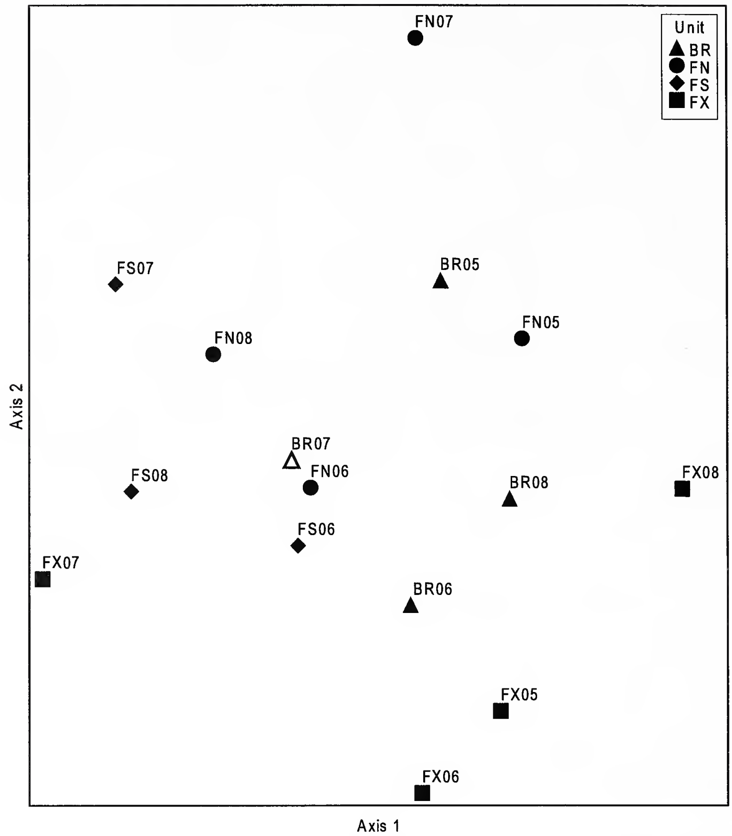

Figure 4. NMS ordination of leaf beetle collection data 2005–2008 (indicated by numbers at end of each label) at Crooked Creek SNP in Kentucky. Symbol types vary for different management units (labeled with letters), and hollow symbols indicate years in which a unit was burned late winter/early spring (prior to sampling).

units. Composition within units between years appears fairly consistent, with units BU and LG well clustered, with FBG, NGU, and GU being more scattered. The restorations generally appear more dissimilar, being spread out over more space than the remnant units. Leaf beetle composition from units at Crooked Creek SNP (Figure 4) appears quite spread both within and between units, and with no clear separation of restoration units (FS and FN). The two units of Blue Licks SPNP (Figure 5) do separate as the higher quality remnant (OT) and restoration unit (Smoot). Composition at Thompson Creek SNP (Figure 6) appears quite similar between years for units SP and NE, the main larger glades, while composition of the smaller isolated glades (NW and NNW) appears more variable between years. The three barrens at Eastview SNP (Figure 7a) are generally grouped together in ordination space, although they appear fairly spread out. All three units in years burned appear somewhat separated from their unburned years, but the separate analysis of the middle barren (Figure 7b) reveals virtually no difference in leaf beetle composition between the burned and unburned half in 2007.

A closer look at the species considered rare (Hall and Barney 2010), revealed a number of state records for Kentucky from each preserve (Table 1). Of these 23 state records, nine species have only been found in a single preserve ('unique locale'), while the remainder have been found in multiple state nature preserves or other protected areas. The nine unique locale species (with number of specimens in parentheses) by preserve are: Raymond Athey: *Chrysolina quadrigemina* (Suffrian) (5), *Erepsocassis rubella* (Boheman) (14), *Graphops simplex* J. L. LeConte (2), *Microrhopala rileyi* S. Clark (11), and *Tria-*

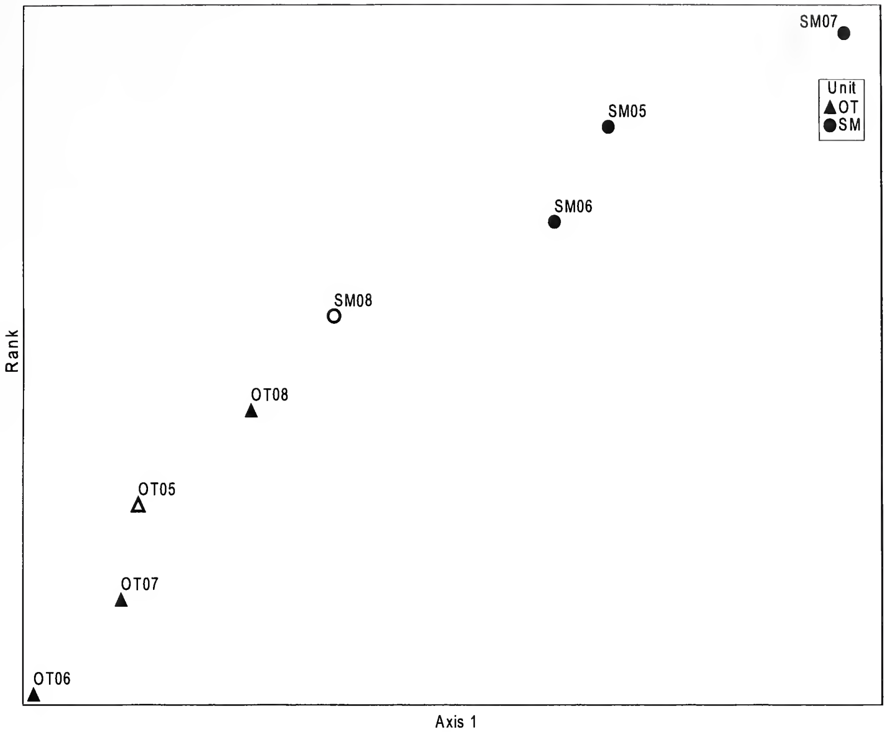

Figure 5. NMS ordination of leaf beetle collection data 2005–2008 (indicated by numbers at end of each label) at Blue Licks SPNP in Kentucky. Symbol types vary for different management units (labeled with letters), and hollow symbols indicate years in which a unit was burned late winter/early spring (prior to sampling).

chus atomus (Suffrian) (1); Blue Licks: *Phyllobrotica stenidea* Schaeffer (5); Thompson Creek: *Ceraltica insolita* (F. E. Melsheimer) (1); and Eastview Barrens: *Colaspis suilla suilla* F. (1) and *Metachroma orientale* Blake (1). Of these, all but three species at Athey SNP were not only unique to one preserve, but to one management unit within the preserve.

DISCUSSION

All five state nature preserves in this study were home to many rare chrysomelids. We found differences in species richness and composition that identified Raymond Athey Barrens SNP as having the highest diversity of leaf beetles, Blue Licks SPNP having the lowest, and the other three preserves falling somewhere in the middle. The presence of rare species (including ones for which a single preserve was their unique locale) in all five preserves demonstrates the important role they each play in providing habitat for this little-studied group of organisms. The variability in species and specimen number within preserves between years demonstrates the highly dynamic nature of leaf beetles. While very little is known about the life cycle of many species, in general they display very short periods of activity when they can be easily captured by sweep nets.

Our results generally suggest that populations of leaf beetles within native grasslands in Kentucky are persisting in managed preserves. We were somewhat surprised and encouraged by the lack of a clear drought effect in 2007 on leaf beetles across preserves. In general, leaf beetle composition appeared more similar within management units between years than within years between units, suggesting stronger effects of vegetation and other *in situ* factors compared to weather or other broader-scale patterns. Given the perennial nature of most plants, including a number of known host plants (Barney and Hall 2011) within these grassland habitats, this is not entirely surprising. The results of NMS ordinations suggest the possibility that leaf beetle compo-

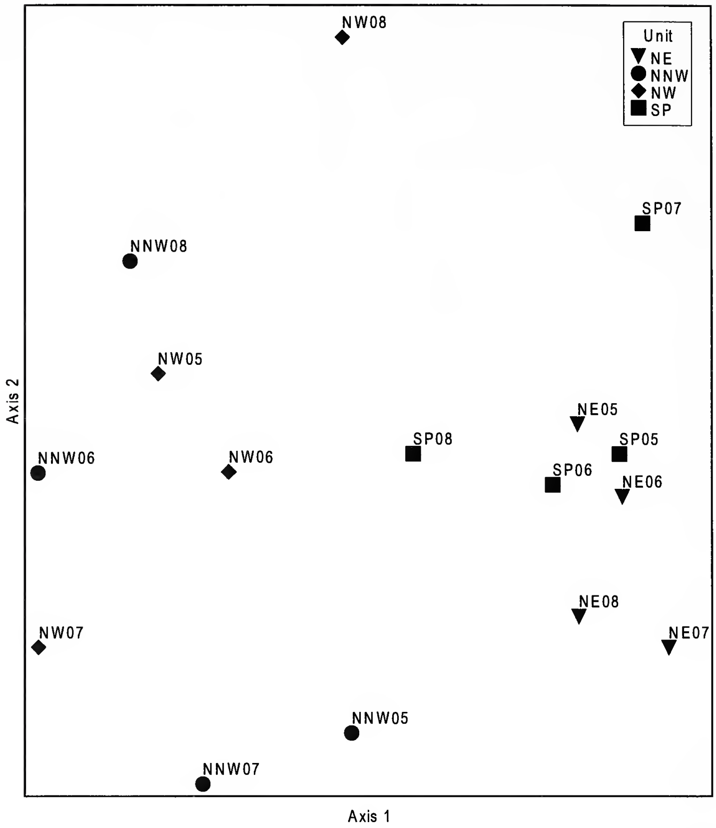

Figure 6. NMS ordination of leaf beetle collection data 2005–2008 (indicated by numbers at end of each label) at Thompson Creek Glades SNP in Kentucky. Symbol types vary for different management units (labeled with letters).

sition is more variable in restoration units compared to remnant habitats (at Athey SNP) and in very small units compared to larger ones (at Thompson Creek SNP). In addition, the presence of three out of five unique locale species in more than one management unit at Athey SNP compared to none at the other preserves suggests larger barrens (present at Athey SNP) are able to support larger and more widespread populations of rare beetles. This coupled with the high species richness and sample area of Athey SNP demonstrate support for the species-area relationship presented by MacArthur and Wilson (1967).

Finally, we did not find a clear impact of prescribed fire on leaf beetle species composition based on NMS ordinations. The subset from Eastview SNP showed that in the year one-half of the middle barren was burned, both halves/units were more similar in composition than in any other sampling years. In previous analyses, we found no significant effect of prescribed burns on species richness of leaf beetles or vegetation at Raymond Athey SNP and Eastview SNP (Hall and Barney, unpublished data). Panzer (1998) and Swengel and Swengel (2001) have noted difficulty in assessing insect abundance before and after burning due to low numbers beforehand. We also encountered difficulty in examining species-specific impacts due to low numbers, but NMS ordinations should reveal any large impacts reflected in species composition, and we did not find evidence of any. Tooker and Hanks (2004) found no impacts of burning on insects living within stems of *Silphium* spp. They even found live insects in stems collected directly after the burn. While very little is known about the life history of many chrysomelids, many overwinter in the litter layer, and may be present as adults or pupae during late winter when burns are typically conducted. There is much literature and research on fire behavior, and

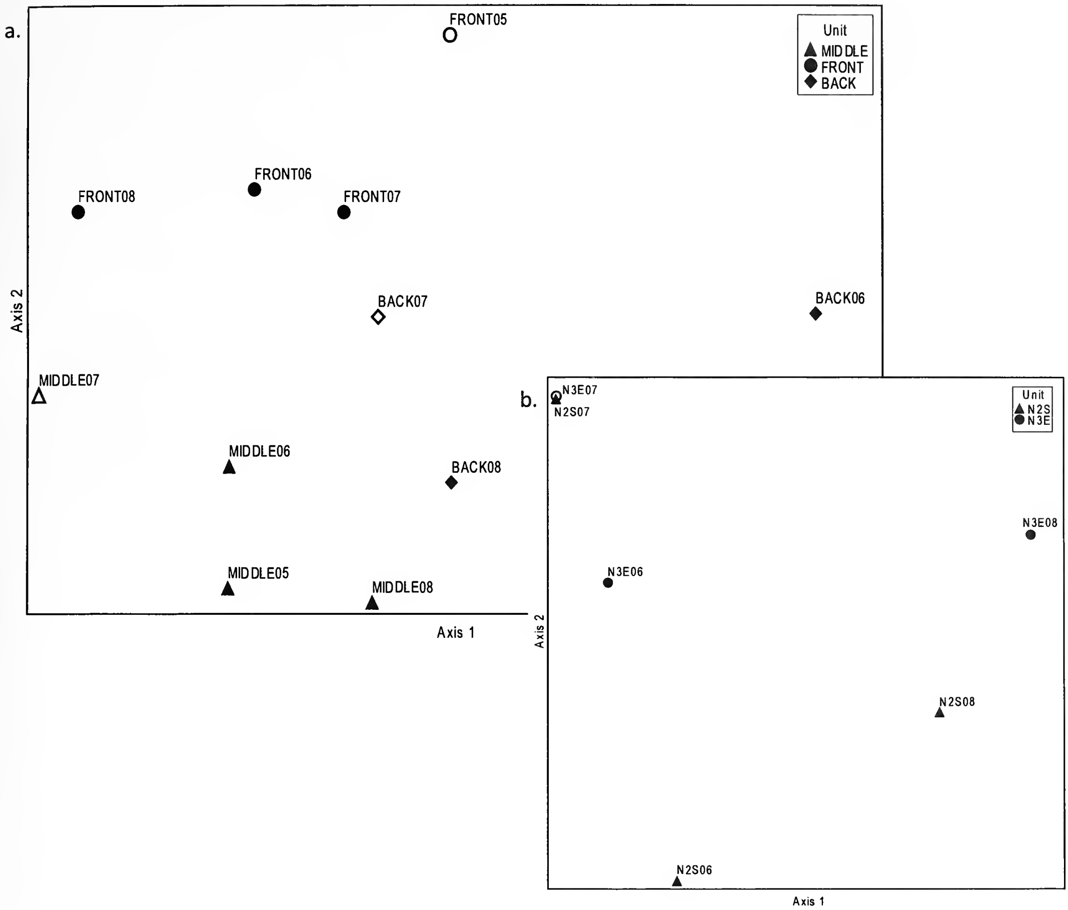

Figure 7. NMS ordination of leaf beetle collection data 2005–2008 (indicated by numbers at end of each label) at Eastview Barrens SNP (a.). A subset of data from Eastview SNP was also examined to detect differences in burned units (b). Symbol types vary within each ordination for different management units (labeled with letters), and hollow symbols indicate years in which a unit was burned late winter/early spring (prior to sampling).

in general the effects of prescribed fire are patchy—with intensity in a given spot dependent on many variables which change over the course of a landscape and during the time it takes for the fire to burn. Rhoades et al. (2002) found temperatures at 10 cm height to range from 250 to 400°C (using fire-sensitive paints), and in monitoring temperatures at the groundlayer using the same paints during a prescribed burn conducted by KSNPC at Crooked Creek SNP in 2009, we found differences of 264°C. While we did not find clear impacts of prescribed burns in the current study, we cannot rule out direct negative impacts on leaf beetle populations. It may be that burned units were recolonized in the same year by individuals from adjacent unburned units. For this reason, we encourage the continued use of small management units by KSNPC to minimize impacts on leaf beetles. Given that six of the nine unique locale species were found in only one management unit within the preserve, use of small management units is likely better for leaf beetles compared to large ones.

We posit that leaf beetles can serve as a useful indicator of overall biodiversity in grassland habitats. They are inextricably linked with vascular plant diversity, as each species must have its associated host plant(s) in order to persist. In efforts to identify host plants for some of these beetles, we have found a number of families and genera which are species rich in native grassland communities. These include legumes (Fabaceae), oaks (*Quercus* spp.), and St. John's worts (*Hypericum* spp.) (Barney and Hall 2011). In addition, when we compared composition of vascular plants listed on the KSNPC species lists for each preserve and leaf beetle composition in terms of relative abundance (we used categories of Jones 2005 for plants and Hall and Barney 2010 for leaf beetles) we found a significant regression for the rare (P = 0.005, R^2 = 0.70) and infrequent (P = 0.01, R^2 = 0.63) categories (Hall and Barney, unpublished data). In addition, of all leaf beetles known to occur in Kentucky only seven of 253 (2.8%) are non-native (Hall and Barney 2010).

In conclusion, we found clear differences in leaf beetle diversity between the five state nature preserves included in this study. Year to year changes in leaf beetle composition did not appear significantly influenced by a statewide drought in 2007. All five preserves contained multiple rare leaf beetle species, with four of the five containing beetle species found only there. Ordinations revealed variation in beetle composition, sometimes between restorations and remnant habitats, and sometimes clearly between different management units. Prescribed burns conducted to manage these grassland habitats had no clear negative impact on their populations. We encourage continued management using small units to minimize any negative impact. The high number of rare species highlights the importance of nature preserves as habitats for this group, with a need for more study in order to identify species of concern for state listing. Finally, due to the dependence of this insect group on vascular plants, as well as their role in trophic interactions, leaf beetles are an underutilized group of biota that should serve as good indicators of overall biodiversity.

ACKNOWLEDGEMENTS

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Appendix. List of leaf beetles species (Coleoptera: Chrysomelidae) collected in five state nature preserves in Kentucky during 2005–2008. Number given is total specimens. *denotes state record.

	Athey SNP	Crooked Creek SNP	Blue Licks	Thompson Creek SNP	Eastview SNP	Total
Agroiconota bivittata (Say)	42	5	0	1	2	50
Altica knabii Blatchley*	0	3	0	0	0	3
Altica litigata Fall	1	0	0	0	0	1
Altica sp. 1	0	1	1	0	1	3
Anisostena ariadne (Newman)*	17	0	0	0	0	17
Anisostena nigrita (Olivier)	0	6	0	23	4	33
Anomoea laticlavia laticlavia (Forster)	4	1	0	4	13	22
Babia quadriguttata quadriguttata (Olivier)	2	8	0	0	2	12
Bassareus clathratus (F. E. Melsheimer)	3	0	0	0	19	22
Bassareus formosus (F. E. Melsheimer)	0	0	0	1	0	1
Bassareus lituratus (F.)	21	18	4	0	25	68
Blepharida rhois (Forster)	0	0	0	1	13	14
Brachypnoea clypealis (Horn)	17	2	0	5	8	32
Brachypnoea convexa (Say)	2	0	0	0	0	2
Brachypnoea margaretae (Schultz)	1	126	16	8	137	288
Brachypnoea puncticollis (Say)	41	2	0	42	0	85
Brachypnoea tristis (Olivier)	1	0	1	0	0	2
Calligrapha bidenticola Brown	0	1	0	0	0	1
Capraita circumdata (Randall)*	0	1	0	4	0	5
Capraita sexmaculata (Illiger)	1	2	2	1	0	6
Capraita thyamoides (Crotch)	9	7	2	4	2	24
Ceraltica insolita (F. E. Melsheimer)*	0	0	0	1	0	1
Cerotoma trifurcata (Forster)	27	0	8	9	10	54
Chaetocnema confinis Crotch	0	1	0	0	1	2
Chaetocnema denticulata (Illiger)	1	0	1	5	0	7
Chaetocnema fuscata R. White	1	0	0	0	0	1
Chaetocnema pinguis J. L. LeConte	0	0	0	1	0	1
Chaetocnema pulicaria F. E. Melsheimer	0	1	0	0	0	1
Chalepus bicolor (Olivier)	1	0	1	2	0	4
Charidotella purpurata (Boheman)	1	0	0	0	0	1
Charidotella sexpunctata bicolor (F.)	9	0	0	0	2	11
Chelymorpha cassidea (Fabricius)	23	1	0	0	0	24
Chrysochus auratus (F.)	6	14	4	0	0	24
Chrysolina cribaria (Rogers)	1	0	0	1	0	2
Chrysolina quadrigemina (Suffrian)*	5	0	0	0	0	5
Colaspis brunnea (F.)	46	16	12	10	22	106
Colaspis suilla suilla F.*	0	0	0	0	1	1
Coleothorpa dominicana dominicana (F.)	10	6	5	0	13	34
Crepidodera browni Parry	0	26	0	1	0	27
Crepidodera longula Horn	0	13	0	0	0	13
Cryptocephalus notatus F.	0	0	0	0	1	1
Cryptocephalus quadruplex Newman	3	0	0	1	1	5
Cryptocephalus striatulus J. L. LeConte*	41	1	0	0	0	42
Cryptocephalus venustus F.	96	19	13	1	2	131
Deloyala guttata (Olivier)	19	1	0	4	4	28
Derocrepis erythropus (F. E. Melsheimer)	0	1	2	0	0	3
Diabrotica cristata (Harris)	22	0	0	0	24	46
Diabrotica undecimpunctata howardi Barber	3	0	1	0	1	5
Diachus chlorizans (Suffrian)	0	0	0	0	9	9
Dibolia borealis Chevrolat	1	0	1	0	0	2
Disonycha admirabila Blatchley	17	11	6	6	12	52
Disonycha discoidea (F.)	0	0	0	1	0	1
Disonycha glabrata (F.)	1	0	2	6	1	10
Disonycha xanthomelas (Dalman)	0	0	0	1	0	1
Epitrix brevis Schwarz	1	0	0	0	1	2
Epitrix fuscula Crotch	1	0	0	1	0	2
Erepsocassis rubella (Boheman)*	14	0	0	0	0	14
Exema canadensis Pierce	30	35	15	0	7	87
Exema dispar Lacordaire	12	13	1	2	17	45
Glyptoscelis pubescens (F.)	0	0	0	1	0	1

Appendix. Continued.

	Athey SNP	Crooked Creek SNP	Blue Licks	Thompson Creek SNP	Eastview SNP	Total
Graphops curtipennis curtipennis (F. E. Melsheimer)	13	7	0	0	8	28
Graphops marcassita marcassita (Crotch)	4	0	4	0	0	8
Graphops simplex J. L. LeConte*	2	0	0	0	0	2
Graphops varians J. L. LeConte*	13	0	0	3	1	17
Griburius scutellaris (F.)	19	7	4	1	15	46
Jonthonota nigripes (Olivier)	1	0	0	0	0	1
Kuschelina perplexa (Blake)	3	2	0	0	0	5
Kuschelina petaurista (F.)	4	2	1	11	3	21
Kuschelina suturella (Say)*	0	1	0	1	0	2
Kuschelina vians (Illiger)	0	2	0	1	0	3
Lema daturaphila Kogan & Goeden	6	1	0	2	2	11
Lexiphanes saponatus (F.)	0	1	0	0	0	1
Longitarsus melanurus (F. E. Melsheimer)	3	3	0	6	1	13
Longitarsus sp. 1	0	1	0	23	3	27
Longitarsus sp. 2	12	0	1	0	2	15
Luperaltica nigripalpis (J. L. LeConte)	0	0	0	0	7	7
Metachroma orientale Blake*	0	0	0	0	1	1
Metachroma pallidum (Say)	2	0	0	0	4	6
Metrioidea brunnea (Crotch)	16	0	0	0	0	16
Microrhopala excavata excavata (Olivier)	0	0	0	5	0	5
Microrhopala rileyi S. Clark*	11	0	0	0	0	11
Microrhopala vittata (Fabricius)	1	33	0	5	0	39
Microrhopala xerene (Newman)	0	0	0	1	1	2
Myochrous denticollis (Say)	1	0	0	0	0	1
Neochlamisus bebbianae (Brown)	2	0	0	2	4	8
Neochlamisus eubati (Brown)	0	1	1	6	4	12
Neochlamisus gibbosus (F.)	0	0	0	0	5	5
Odontota dorsalis Thunberg	0	2	1	0	0	3
Odontota horni J. Smith	4	6	0	17	2	29
Opacinota bisignata (Boheman)	24	0	0	1	0	25
Ophraella americana (F.)	0	21	13	2	96	132
Ophraella communa LeSage	20	3	0	2	12	37
Ophraella conferta (LeConte)	1	5	0	0	7	13
Ophraella cribrata (LeConte)	33	50	12	22	38	155
Ophraella notata (F.)	0	0	0	0	17	17
Orsodacne atra (Ahrens)	0	0	0	0	1	1
Orthaltica melina Horn	4	0	0	0	4	8
Oulema melanopus (Linnaeus)	1	0	0	0	0	1
Oulema palustris (Blatchley)	0	0	1	1	0	2
Pachybrachis hepaticus hepaticus (F. E. Melsheimer)	0	0	0	2	0	2
Pachybrachis luridus (F.)	0	0	0	0	1	1
Pachybrachis m-nigrum (F. E. Melsheimer)	1	0	0	50	0	51
Pachybrachis morosus Haldeman*	5	0	0	0	2	7
Pachybrachis nigricornis carbonarius Haldeman	77	3	12	0	8	100
Pachybrachis othonus othonus (Say)	0	8	4	0	0	12
Pachybrachis pectoralis (F. E. Melsheimer)	1	0	1	0	0	2
Pachybrachis praeclarus Weise*	0	12	1	0	0	13
Pachybrachis spumarius Suffrian	12	0	1	0	27	40
Pachybrachis trinotatus (F. E. Melsheimer)	20	0	0	0	0	20
Pachybrachis viduatus (F.)*	8	0	0	0	9	17
Pachybrachis EGR #29*	114	0	0	0	0	114
Pachybrachis EGR #30*	0	3	2	3	1	9
Pachybrachis EGR #135*	0	15	0	0	12	27
Pachybrachis sp. 1*	0	0	1	2	0	3
Paria sellata (Horn)	11	6	9	3	5	34
Paria thoracica (F. E. Melsheimer)	92	42	26	0	3	163
Paria fragariae fragariae Wilcox	22	21	6	4	16	69
Paria quadrinotata (Say)	0	2	1	0	0	3

Appendix. Continued.

	Athey SNP	Crooked Creek SNP	Blue Licks	Thompson Creek SNP	Eastview SNP	Total
Paria sexnotata (Say)	4	3	0	15	1	23
Phyllecthris gentilis J. L. LeConte	0	0	2	0	11	13
Phyllobrotica limbata (F.)	5	5	0	1	2	13
Phyllobrotica stenidea Schaeffer*	0	0	5	0	0	5
Phyllotreta striolata (F.)	1	0	0	0	0	1
Plateumaris metallica (Ahrens)	0	1	0	0	0	1
Pseudodibolia opima (J. L. LeConte)*	0	1	0	1	0	2
Rhabdopterus deceptor Barber	4	1	0	0	0	5
Saxinis omogera omogera Lacordaire	45	48	19	5	55	172
Scelolyperus liriophilus Wilcox	0	0	0	1	0	1
Stenispa metallica (Fabricius)	1	3	1	8	1	14
Strabala rufa rufa (Illiger)	1	0	0	1	0	2
Strongylocassis atripes (LeConte)	28	5	0	1	3	37
Sumitrosis ancoroides (Schaeffer)	0	0	0	1	0	1
Sumitrosis inaequalis (Weber)	1	1	0	4	3	9
Sumitrosis rosea (Weber)	0	0	0	1	0	1
Systena elongata (F.)	7	0	0	0	9	16
Systena hudsonias (Forster)	0	0	0	0	6	6
Triachus atomus (Suffrian)*	1	0	0	0	0	1
Trichaltica scabricula (Crotch)	1	0	0	0	0	1
Tymnes metasternalis (Crotch)	2	0	0	0	0	2
Typophorus nigritus viridicyaneus (Crotch)	26	0	0	0	0	26
Xanthonia striata Staines & Weisman	2	0	0	0	0	2
Xanthonia villosula (F. E. Melsheimer)	1	0	0	0	0	1
Zygogramma suturalis (F.)	16	1	2	0	2	21
# Specimens	1263	671	229	363	770	3296
# Species	87	70	45	63	72	143
# State Records	10	3	1	5	4	23

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Descriptions of Three New Land Snails from Kentucky

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ABSTRACT

Two new species of land snails, *Patera estillensis*, *Stenotrema macgregori*, and one new subspecies, *Appalachina sayana kentucki*, found in the family Polygyridae are described from eastern Kentucky. *Patera estillensis* is currently known from Estill and Jackson counties only and, therefore, endemic to Kentucky. *Stenotrema macgregori* and *A. sayana kentucki* are currently known from Pike, Letcher, and portions of Harlan County, Kentucky, and Wise County, Virginia.

KEY WORDS: Polygyridae, new species, land snails, *Patera estillensis*, *Stenotrema macgregori*, *Appalachina sayana kentucki*

INTRODUCTION

In Kentucky, as elsewhere, land snails have largely been ignored, frequently being overshadowed by more charismatic wildlife. This has resulted in a substantial deficiency of information on the 194 described land snail species reported from Kentucky, in terms of their distribution, ecology, and shell divergence. Furthermore, it is not uncommon to find land snails that don't fit well within the parameters of a described species. These nonconformist gastropods are often grouped with known taxa (considered only as localized variants) or described as forms, occasionally attaining full species status later (Hubricht 1985). This results when disparities observed in shells are constant but more importantly observed across a larger geographic region. At this point, it becomes necessary to revisit the current taxa for clarification. This is the case for the proposed *Patera estillensis, Stenotrema macgregori,* and *Appalachina sayana kentucki* and the rationale I used for describing the three new species from Kentucky.

Study Area

Woods et al. (2002) placed the study areas (Figure 1) within two ecoregions of eastern Kentucky, the Cumberland Mountain Thrust Block and the Knobs-Lower Scioto Dissected Plateau. The Cumberland Mountain Thrust Block is characterized by steep ridges, hills, coves, narrow valleys, and the Pine Mountain Overthrust Fault. Maximum elevation is greater than elsewhere in Kentucky, Black Mountain reaching 1265 m. Many streams in this ecoregion are cool and high gradient; with a substrate commonly consisting of cobble and boulder. The underlying geology consists of Pennsylvanian shale, siltstone, sandstone, conglomerate, and coal. In particular, the study area is located on Pine Mountain that, in Kentucky, follows a northeast to southwest path, stretching 177 km from Breaks Interstate Park to the Kentucky-Tennessee border. Much of the mountain is the geographic border between Kentucky and Virginia. The forests in this region are considered to be the most biologically diverse of any in the United States (Jones 2005).

The Knobs-Lower Scioto Dissected Plateau is characterized by steep rounded hills and ridges and narrow valleys with high gradient streams. Maximum elevation is around 488 m. Limestone cliffs are common especially in the southern portions of this ecoregion and the high levels of topographic and geologic variation create substantial ecological diversity. On a per site basis, these high knobs in the vicinity of Powell and Estill counties contain the highest reported land snail faunas in North America (Dourson 2007).

METHODS

Multiple shell specimens (in ten separate locations) of the proposed *Patera estillensis* were collected from the base of limestone clifflines above Red Lick drainage in Estill County and compared with known specimens of the closely related *Patera appressa* (Say) and *Patera laevior* Hubricht, found within two kilometers of the same locality of *P. estillensis* sites.

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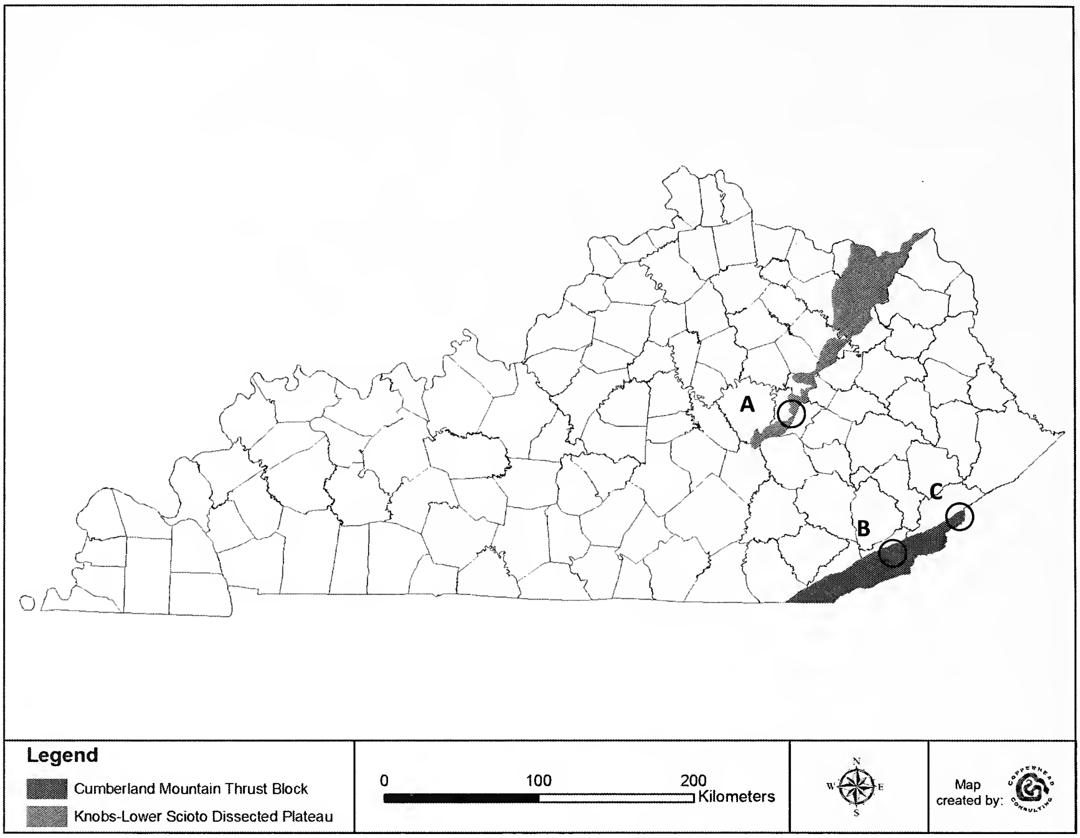

Figure 1. Study Area A, Furnace Mountain in Powell County, Kentucky; Study Area B, Bad Branch Falls State Nature Reserve, Letcher County, Kentucky and Breaks Interstate Park, Pike County, Kentucky.

Specimens of the proposed *Stenotrema macgregori* were collected from hillsides at Breaks Interstate Park in Pike County and from mountainsides at Bad Branch Falls Nature Preserve in Letcher County and compared with the closely related *Stenotrema stenotrema* (Pfeiffer) from the same localities. Shells of the proposed *S. macgregori* also were compared with shells of *Stenotrema angellum* Hubricht collected from Powell and Fayette Counties, which are similar in size and form.

Shells of the proposed *Appalachina sayana kentucki* were collected from hillsides at Breaks Interstate Park in Pike County and from mountainsides at Bad Branch Nature Preserve in Letcher County and compared with known specimens of *Appalachina sayana* Pilsbry collected from the Cumberland Plateau region of Kentucky.

Patera estillensis, Stenotrema macgregori, and *Appalachina sayana kentucki* are described based entirely on their external shell morphology.

RESULTS

The results of the study found that *Patera estillensis, Stenotrema macgregori,* and *Appalachina sayana kentucki* all exhibited constant and reliable differences between closely related and described taxa and are not localized variations in shell morphology. For each of the three new species, detailed descriptions, similar species, habitat, overall status, and their type localities are given below.

All three species described belong to the family, Polygyridae which in turn belongs to the superfamily Helicoidea. Polygyridae is native to North America, making up a significant proportion of the land snail fauna in the eastern portions. They also are found in western North America, northern Central

America, and are present on some Caribbean islands. The members of this family can be found in a wide range of habitats, from humid, mixed-hardwood forests to desert mountain tops. Polygyrids are medium to large (~5–45 mm diameter), with reflected lips, and with shells ranging in shape from subglobose to discoidal. Most polygyrids are known to be mycophagous with foraging behavior occurring mostly at night, when moisture is most abundant. However, they can be found active at any time in more humid conditions. Several species in this family are ranked as G1 or G2 indicating that they may be imperiled (Perez 2004).

The family Polygyridae is distinguished from other gastropods on the basis of several anatomical features: no dart apparatus, muscles united in a single band that allows the eyes and pharynx to be retracted, and jaws that are ribbed.

This family is further defined by an absent diverticulum and absent stimulatory organ. The two subfamilies, Polygyrinae and Triodopsinae, are distinguished on the basis of reproductive anatomy, as some species in the subfamily Polygirinae show a penial appendage. According to Emberton (1991), this family is monophyletic. It contains 23 genera and 277 species (Turgeon et al. 1998).

Patera estillensis, carinate bladetooth, new species (Figure 2G, H, I)

Description: The shell is 15 to 20 mm in diameter, depressed heliciform with a broadly reflected lip. The shell has 4.5–5 whorls and the umbilicus is imperforate. Aperture with a large parietal tooth, the basal tooth is small and poorly defined but an important and constant feature. The shell surface is somewhat glossy, having no hairs at any stage of growth. The transverse striae are well developed on top of shell but weakly defined on the base, and, although the spiral papillae are present, they are sometimes only faintly visible (microscope required to see this micro-feature). The shell periphery is strongly angular to carinate the entire length of the shell (a key feature for the identification of the species). Specimens shown in Figure 2G, H, I are from the type locality.

Similar species: *Patera estillensis* appears to be most closely related to *P. appressa* but has a flatter shell and the entire periphery is strongly angular whereas the shell periphery of *P. appressa* is typically rounded (although some populations of *P. appressa* have weakly angular peripheries). *Patera laevior* has a rounded periphery and spiral striae (incised lines) whereas *P. estillensis* has spiral papillae. *Patera estillensis* was not found to co-exist with *P. appressa* or *P. laevior*.

Habitat: Shells are found among sheltered areas such as rock talus, at the base of limestone cliffs, or in small cracks within the cliff face; live individuals can be found in narrow crevices or around the entrances of small grottos and caves, especially during the dryer mouths of July and August. The species was not found far from carbonate outcrop sources. From the base of the cliffline, *P. estillensis* becomes scarce at downhill sites further than 10 m and at 30 m (from the cliffline), as the species was generally absent where as other land snail species such as *Mesodon zaletus* A. Binney, *Allogona profunda* Say *and Inflectarius rugeli* Shuttleworth remained common. The flat, carinate shape of *P. estillensis* is thought to be an evolutionary response to the snail's compressed habitat of rock crevices.

Status: Endemic to Kentucky. Although in some localities shells are rather common, live individuals in these same locations are uncommon to rare. The copious number of shells found at some sites may be a result of the protective conditions of overhanging cliffs, which are thought to slow the shells rate of decay. Its range in Kentucky appears to be restricted to only a few narrow ridge systems and high knobs above Red Lick Creek in Estill County and a small portion of Jackson County. The species was first discovered by Allen Risk, Morehead State University, who was sampling for mosses in Estill County, Kentucky.

Type locality: Estill County (Figure 1A), Kentucky, Happy Top Mountain above Red Lick Creek, 1.5 km SE of Jinks (located on Daniel Boone National Forest); NAD 83/WGS84, UTM 16 762984E, 4164841N; Elevation 393 meters: Winchester Quad. Both the paratype and holotype will be deposited in the Field Museum of Natural History, Chicago, Illinois.

Etymology: The species' name is derived from the type locality located in Estill County, Kentucky. An estimated 95% of the total

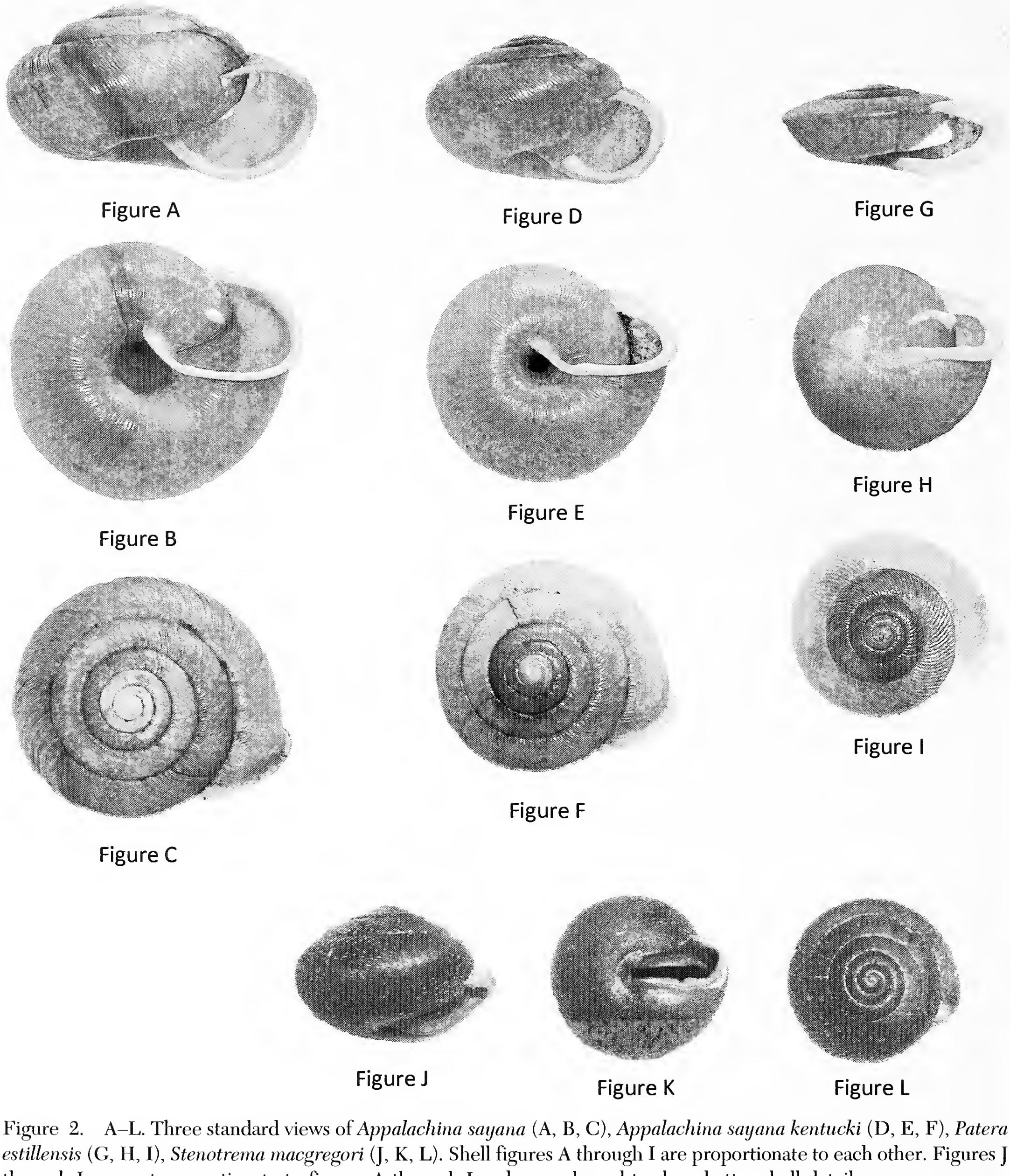

Figure 2. A–L. Three standard views of *Appalachina sayana* (A, B, C), *Appalachina sayana kentucki* (D, E, F), *Patera estillensis* (G, H, I), *Stenotrema macgregori* (J, K, L). Shell figures A through I are proportionate to each other. Figures J through L are not proportionate to figures A through I and are enlarged to show better shell detail.

known range of the snail lies in Estill County with the remaining 5% found in Jackson County.

Key: Refer to *Kentucky's Land Snails and their Ecological Communities* (Dourson 2011)

Stenotrema macgregori, fraudulent slitmouth, new species (Figure 2J, K, L)

Description: The shell is 8 to 10 mm in diameter, pill-shaped, with a slightly reflected lip. The shell has 5–6 whorls and the umbilicus is imperforate. The aperture has a long parietal tooth as in all *Stenotrema* species. The shell is cinnamon-buff and short stiff hairs are present on the entire surface, but hairs are often lost in older shells. The transverse striae are poorly developed. The basal notch is shallow and the interdenticular sinus is indistinct in most specimens. The fulcrum is well developed but short. Specimens shown in Figure 2J, K, L are from the type locality.

Similar species: *Stenotrema stenotrema* (which *Stenotrema macgregori* has likely been confused with in the past) is 2–3 mm larger, has a deeper basal notch, more-closed aperture and the interdenticular sinus is notably deeper. The two species are often found together and can readily be separated by size alone. *Stenotrema macgregori* refers to *S. angellum* but has a more compact shape, is more hirsute, has a higher shell profile and a darker periostracum.

Habitat: A habitat generalist found at mid-elevation, rich hardwood forests under a variety of forest litter but apparently is absent from the dryer mountain tops, dense rhododendron thickets, hemlock, and Virginia pine forests of Pine Mountain. The highest numbers of shells were found in mixed-mesophytic sites, suggesting a partiality for this habitat.

Status: This species appears to be restricted to upper elevation hardwood forest of Pine Mountain, from Breaks Interstate Park to Bad Branch SNP and is generally uncommon where it occurs.

Type locality: Pike County (Figure 1C), Kentucky, hillside above Russell Fork, 1.6 km SE of Elkhorn City, (located on Breaks Interstate Park); NAD 83/WGS84, UTM 17 381718E, 4128162N; Elevation 335 meters; Pikeville Quad. Both the paratype and holotype will be deposited in the Field Museum of Natural History, Chicago, Illinois.

Etymology: *Stenotrema macgregori* is named in honor of my good friend and mentor, John Macgregor.

Key: Refer to *Kentucky's Land Snails and their Ecological Communities* (Dourson 2011).

Appalachina sayana kentucki, Pine Mountain crater, new subspecies (Figure 2D, E, F)

Description: The shell is 18 to 22 mm wide, Heliciform with a reflected lip. The mature shell has 5.5 whorls is thin, umbilicate to rimate and is usually without a parietal tooth. There is a small basal tooth present but the shell is without a palatal tooth. The color is a pale-yellow to pale olive-tan and there are no hairs at any stage of growth. The transverse and minute spiral striae are always present and the shell periphery is well rounded. Specimens shown in Figure 2G, H, I are from the type locality.

Similar species: *Appalachina sayana* (Figure 2A, B, C) is around 10 mm larger, has a wider umbilicus, a parietal tooth (*A. sayana kentucki* is typically without this tooth), smaller basal tooth and a thin wire-like lip (the lip of *A. sayana kentucki* is wider, remaining somewhat concave in shape its entire length). The umbilicus of *A. sayana* is umbilicate where as the umbilicus of *A. sayana kentucki* is more or less rimate. *Appalachina chilhoweensis* (Lewis) is 15 to 22 mm larger, has a wider umbilicus and is without teeth.

Habitat: A relatively common species of rich upland and higher elevation mixed hardwood forests. It is generally found under moist leaf litter and other forest debris, becoming less common in dryer sites such as ridgetops and Virginia pine forests. The highest numbers of shells were found in mixed-mesophytic sites, suggesting a partiality for this habitat.

Status: In Kentucky this species appears restricted to Pine and Black Mountains, although it is a relatively common species when found. This gastropod merits further investigation into its range and overlap with *A. sayana.*

Type locality: Letcher County (Figure 1B), Kentucky, Pine Mountain, 2 km SE of Ermine (located on Bad Branch Falls State Nature Preserve); NAD 83/WGS84, UTM 17 341910E, 4107625N; Elevation 606 meters; Pikeville Quad.

Etymology: *Appalachina sayana* was a species first documented and studied more closely in the mountain counties of Kentucky and appears to be restricted to this region.

Type: Both the paratype and holotype will be deposited in the Field Museum of Natural History, Chicago, Illinois.

Key: Refer to *Kentucky's Land Snails and their Ecological Communities* (Dourson 2011).

DISCUSSION

Not since 1962, when John B. Burch published his classic work, "How to Know the Eastern Land Snails," has there been a single source for the identification of eastern land snails. Since then, many new species have been described (Hubricht 1985), forms have been elevated to species, and there have been a number of taxon revisions. Most of these species were originally described on external shell morphology only (Pilsbry 1940, 1946, 1948; Hubricht 1985), and, although many of these species have been revisited by later investigators who did anatomical work (Emberton 1991; Nekola and Coles 2010), nearly all have survived (at a species level) taxonomic revision. Describing new snail species based exclusively on shell morphology is still used and a accepted practice (Fred Thompson pers. comm.).

In Kentucky, at least three species have escaped taxonomic review, resulting in this paper. For example, there are consistent discrepancies found between *Appalachina sayana* and *Appalachina sayana kentucki*, and, although some of the incongruities were noted by past collectors, they were inadequately discussed in the literature (Pilsbry 1940; Branson 1973; Branson and Batch 1968; Hubricht 1985; Branson and Batch 1988). The differences I have observed between *A. sayana* (from the Cumberland Plateau) and *A. sayana kentucki* (from Pine Mountain) however have been distinct and remarkably constant, making their separation straightforward. Areas of overlap for the two species have not yet been found in Kentucky but likely occur around Pine Mountain State Park, Breaks Interstate Park and the Cumberland Plateau.

Other species such as *Stenotrema macgregori* were perhaps lumped with more common and widespread land snails such as *Stenotrema stenotrema*. It superficially resembles that species but was probably seen as an anomaly within the *S. stenotrema* clan, the differences in their shell morphology thought to be a localized variation. A closer examination of the external characteristics between the two species however has clearly shown distinctive and constant dissimilarity across all localities collected to date but more importantly also show dissimilarity when found together. Past snail inventories by Branson, Hubricht, and others have more than likely included *S. macgregori* in their collections but may have missed collecting the two species together. When *S. stenotrema* and *S. macgregori* are found coexisting, the shells remain divergent in size and aperture structure. In particular, they have a dissimilar basal notch and interdenticular sinus.

Patera estillensis was not likely in past collections, a result of the snail's small geographic range (currently known as only several square miles) and its affinity for isolated carbonate cliffs located on steep and narrow ridge systems (where there are generally no roads or trails) high above the valley floor. No specimens of this species were found in the Branson collections at Eastern Kentucky University nor did Branson, Hubricht, or Pilsbry refer to this noteworthy land snail in any of their publications.

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A Critical Evaluation of the Kentucky Phosphorus Index

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ABSTRACT

The U.S. Department of Agriculture's Natural Resource Conservation Service (USDA-NRCS) is currently revising its 590 Nutrient Management Conservation Standard. As part of this revision, USDA-NRCS is considering requiring states to test the accuracy of their phosphorus (P) indices using either measured P loss data or simulated P loss data generated from process-based models. The objective of this study was to critically evaluate the KY P index by comparing index output with simulated P loss data obtained from a validated P loss model. Furthermore, the general formulation of the index was evaluated against current research on the processes controlling P transport in the environment. Results suggested that in some areas the index does a good job in assigning P loss risk; however, this analysis also showed some important deficiencies in the index, primarily the neglect of important factors known to affect P loss (e.g., soil erosion and P application rates) and how the different factors in the index are weighted. To reduce the amount of P that is exported from agricultural fields to waterways within Kentucky, resources should be devoted to revising the KY P index to address these limitations as well as developing long-term monitoring sites where the P index and more process-based models can be evaluated against measured P loss data.

KEY WORDS: Phosphorus, P Index, 590 Standard, phosphorus loss, phosphorus modeling

INTRODUCTION

Accelerated eutrophication due to excess P loading is widespread among freshwater bodies of the U.S. (National Research Council 2008) with a sizeable portion of the P originating from agricultural fields (U.S. Environmental Protection Agency 2010). In response to water-quality concerns over P export from agricultural fields to surface waters, the USDA's Natural Resource Conservation Service (USDA-NRCS) revised its 590 Nutrient Management Conservation Standard to include P-based planning strategies to restrict P application to fields where the risk of P loss is high (USDA and USEPA 1999). The resulting 590 Standard prescribed three different strategies which states could adopt to rate a field's vulnerability to P loss: agronomic soil test P, environmental threshold soil test P, and the P index. Kentucky has adopted both the environmental P threshold and P index for P-based planning strategies. In general, the P index is considered to be less restrictive than an environmental P threshold (Sharpley et al. 2001).

The P index is an assessment tool developed to identify fields which are most vulnerable to P loss by accounting for the major source and transport factors controlling P movement in the environment (Lemunyon and Gilbert 1993). Each factor included in the index is weighted in such a way as to reflect that factor's perceived importance on P loss. Since its inception, the P index has been revised several times and has been adopted in many different forms throughout the U.S. (Sharpley et al. 2003). Revisions include multiplying source and transport factors rather than summing them, including a contributing distance factor in the index, use of continuous values for some input variables, inclusion of factors to account for best management practices, and calculating an actual P load rather than a relative risk.

The flexibility of the P index allows states to tailor their indices to reflect the dominant factors governing P transport in their region. In developing a P index, a state must determine which field characteristics to include and how to weight each of them. Ideally, a P index should be developed by correlating measured edge-of-field P losses to field-specific characteristics. Given the dearth of available P loss data, however, many P indices have been developed based on professional judgment. This includes the factors within the index, how each factor is weighted, how the final P index value is calculated, and what the final values mean in relation to P planning.

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The Kentucky P index includes 10 field characteristics and 4 ratings (NRCS 2001). The index is used to assign risk of P loss based on a field's runoff potential, soil erosion potential, soil test P (STP) concentration, distance to receiving water body, location, P application method, impairment status of receiving water body, and width of vegetative buffer (Table 1). Each field characteristic is weighted by a factor of 1, 2, or 3 to reflect that factor's perceived importance on P loss. Each site characteristic is assigned a value rating of 1, 2, 4, or 8 points representing low, medium, high, and very high risk of P loss, respectively. The weighted value ratings for each characteristic are summed to obtain a final P index value. The value of the P index is then used to determine whether P application needs to be restricted (Table 2). The weighted factors included in the index were based on the professional judgment of the technical specialists who developed the 590 Standard for KY (NRCS 2001).

To this author's knowledge, the KY P index has not been modified since its initial formulation, nor has it been critically evaluated. Given the large amount of research that has been conducted since the KY P index was first developed, it seems reasonable that the index should be critically evaluated in light of this recent research. Ideally, a P index should be evaluated against observed P loss data. However, due to the lack of edge-of-field P loss data, only a handful of studies exist that compare observed edge-of-field P loss data with a P index (Sharpley et al. 2001; Eghball and Gilley 2002; DeLaune et al. 2004a, 2004b; Harmel et al. 2005; Sonmez et al. 2009). While several of these studies do show a good correlation between the P index and observed P loss, the P index is still far from being considered a validated model. When observed P loss data are not available to test P indices, simulated P loss data generated from process-based models may be a suitable alternative provided the model has been validated for the region of interest (Veith et al. 2005). Indeed, as part of the 590 Standard revision process a Working Group of scientists within the Southern Extension-Research Activity Group 17 (SERA-17) recently recommended that states be required to evaluate their P index against simulated P loss data when measured P loss data are unavailable (Sharpley et al. 2011). Therefore, the objective of this study was to critically evaluate the KY P index by comparing the output with simulated P loss data obtained from a validated P loss model to identify areas where the index may need revising. Moreover, the general formulation of the KY P index was evaluated against current understandings of the processes controlling P transport in the environment.

MATERIALS AND METHODS

The potential for P loss from an agricultural field will depend on the amount of P available in the soil, applied fertilizers, and applied manures as well as the transport potential from runoff, leaching, and erosion. In this study the KY P index was evaluated by assessing how well the index accounts for these different source and transport factors. Where appropriate, the KY P index was evaluated against output from a process-based model. This involved comparing KY P index values with P loss data generated using a process-based P loss model for hypothetical fields with varying runoff rates, erosion rates, STP values, and field slopes. When output from the index could not be directly compared with output from the model, the index was evaluated against current understandings of the processes controlling P movement through the landscape. This included P application method, timing, and amount; distance from P application to surface water; potential for P leaching through the subsurface; and formulation of the index.

In this study the Annualized Phosphorus Loss Equation (APLE) model of Vadas et al. (2009) was used to evaluate the KY P index. The APLE model is a spreadsheet model comprised of a suite of empirical and process-based equations that estimate annual P loss from the landscape when surface runoff is the dominant pathway of P loss. These equations have been calibrated and validated from multiple experiments ranging from soil boxes to field plots and have proven to be robust in their prediction of P runoff under a variety of conditions.

Output from the KY P index and the APLE model were compared under field conditions in which soil P is the only available P source and surface runoff is the dominant loss

Table 1. Kentucky P index (NRCS 2001).

Field feature	Weighting factor	Value ratings			
		Low (1 point)	Medium (2 points)	High (4 points)	Very high (8 points)
Hydrologic soil group	1	A	B	C	D
Residual soil test P level (mg/kg)	3	200–250	251–400	401–533	>533
Field slope (%)	1	<2	2–5	6–12	>12
Land cover (%)	3	60–90	30–60	15–30	0–15
Vegetative buffer width (ft)	3	>29	20–29	10–19	<10
Impaired watershed?	1	NO			YES
Application timing	3	June–September	April, May, October; March or November w/winter cover	March or November w/o winter cover; Febuary w/winter cover	December, January, February
Application method	3	Injected	Surface applied and incorporated within 48 hr.	Surface applied and incorporated within 1 month	Surface applied and unincorporated for greater than 1 month
Downstream distance from application area to spring or waterbody	2	Over 150 ft	50–100	0–50	Adjacent
County location	1	Bluegrass region	All other		

pathway. Under these conditions P can be transported off site in surface runoff either as dissolved P or P attached to eroding soil particles. The KY P index accounts for risk of P loss from soil with soil test P (STP), hydrologic soil group (HSG), field slope, and percent land cover where STP represents the P source contribution and hydrologic soil group, field slope, and percent land cover are used to rate the risk of runoff and erosion. To account for the risk of P loss due to STP, the index rating for STP increases from 1 for Mehlich-3 soil test P (STP) values ranging from 400 to 500 lbs/acre to 4 for STP values ranging from 800 to 1066 lbs/acre (Table 1). For soils with STP values below 400 lbs/acre the P index is not required. And while a value of 8 is given for STP concentrations exceeding 1066 lbs/acre, this is the STP value at which no further P can be applied. To account for the role of runoff in P loss risk, the index rating increases with decreasing soil infiltration capacity as classified by hydrologic soil group (HSG). NRCS classifies soils into four HSGs (A, B, C, and D) based on a soil's infiltration capacity. Soils in group A have low runoff potential and are given a rating of 1 whereas soils in group D have high runoff potential and thus are given a rating of 8 in the index. The index also increases in value with increasing field slope and decreasing land cover (Table 1), presumably due to increased erosion potential, though the KY 590 Standard is not clear on this point (NRCS 2001).

The APLE model calculates annual dissolved P loss as increasing linearly with soil labile P and runoff:

$$DP_{soil} = C \cdot LP \cdot Q \cdot 0.1 \quad (1)$$

where DP_{soil} is annual dissolved P loss from soil (kg/ha), C is an extraction coefficient equal to the slope of a line relating labile P to runoff P (assumed here to be 5×10^{-4}; Vadas et al. 2009), LP is labile P (mg/kg) and was assumed to equal 50% of Mehlich-3 STP (Vadas et al. 2009), Q is annual runoff in mm, and 0.1 is a unit conversion factor to obtain units of kg/ha.

The APLE model calculates annual particulate P loss using the sediment loading function of McElroy et al. (1976) and Williams

Table 2. Risk of P loss based on P index and corresponding nutrient application rate.

Final P index value	Risk of P loss	Nutrient application rate
<30	Low	Nitrogen based
30–60	Medium	Nitrogen based
61–112	High	P based (crop removal)
>112	Very High	No P application

and Hann (1978):

$$P_{sed} = SL \cdot SP \cdot PER \cdot 10^6 \qquad (2)$$

where P_{sed} is annual sediment-bound P lost in runoff (kg/ha); SL is annual soil lost through erosion (kg/ha); SP is total soil P (mg/kg) determined as the sum of active, stable, and organic P pools and is generally correlated with LP; 10^6 is a unit conversion factor to obtain units of kg/ha; and PER is the P enrichment ratio representing the ratio of P in eroded sediment to that in the soil calculated as (Vadas et al. 2009):

$$PER = EXP(2.2 - 0.25 \cdot \ln(SL)) \qquad (3)$$

Annual runoff required for Eq. [1] was calculated with the SCS curve number method (U.S. Department of Agriculture, Soil Conservation Service 1972):

$$Q_d = \frac{(P_d - I_a)^2}{(P_d - I_a + S)} \text{ for } P_d > 0.2 \cdot S \qquad (4)$$
$$\text{otherwise } Q = 0$$

where Q_d is daily runoff (mm), P_d is daily precipitation in (mm), and I_a is initial abstraction (mm) of water assumed to equal 20% of the maximum potential water retention by the soil (S; mm). The maximum potential water retention parameter is calculated from the curve number (CN) by:

$$S = 25.4 \cdot \left(\frac{1000}{CN} - 10\right) \qquad (5)$$

where CN is a function of hydrologic soil group, cover type, treatment, hydrologic condition, and antecedent moisture condition. To evaluate whether the KY P index adequately accounts for the effect of field slope on P loss, S values were modified for slopes of 1.5, 3.5, 9, and 13% following the method used in the Annualized Policy/Environmental Extender (APEX) model (Gassman et al. 2009):

$$S_\beta = S\left(1.1 - \frac{\beta}{\beta + \exp(3.7 + 0.021 * \beta)}\right) \qquad (6)$$

where S_β is the slope-adjusted retention parameter and β is field slope.

Annual soil loss needed for the APLE model was calculated using the Revised Universal Soil Loss Equation Version 2 (RUSLE2) (USDA-ARS 2006). Erosion rates were calculated for field slopes of 1.5, 3.5, 9, and 13% representing low, medium, high, and very high index risk values, respectively. Curve numbers required for equation 5 were also obtained from RUSLE2.

The KY P index was evaluated by determining whether risk values generated by the index were positively correlated with output generated from the APLE model for varying STP, runoff potential, and field slope. Specifically, simulated P loss data were generated using erosion and runoff data calculated for four soil series found in Grayson County, KY representing three hydrologic soil groups (B, C, and D) and a range in soil erodibility factors (Table 3). Simulations were performed for three standard 1-yr crop rotations available for Crop Management Zone 63 in RUSLE2. These included tall fescue forage hay, no-till winter wheat, and no-till corn grain with fall weeds. Runoff data were generated using a 30-yr daily precipitation record for Leitchfield, KY (average annual precipitation is approximately 1200 mm). Average daily runoff values were summed over the entire year for each year to obtain annual runoff values. The average of these annual runoff values was then used in the simulations.

Index values for the simulated fields were calculated by assigning a high risk rating (8 points) to vegetative buffer width and downstream distance because the APLE model generates edge-of-field P loss data and does not account for vegetative buffers or distance to receiving water body. Thus, the comparisons in this study ignore any setback requirements to focus solely on how well the index represents edge-of-field P loss. Application method was also assigned a high risk rating whereas impaired watershed, application timing, and county location were all assigned a risk rating of low (1 point). Land cover rating was assigned a medium risk value (2 points) for the forage hay simulations whereas a low risk rating was assigned to the wheat and corn simulations based on the RUSLE2-calculated vegetative surface coverage at time of P application.

Rainfall and soil data used for comparing the KY P index and the APLE model were chosen from Grayson County strictly for convenience and not intended to be representative of the entire Commonwealth. Instead, the objective of this study was to assess the general trend of the KY P index against output from a process-based model to identify potential limitations with the index. Comparisons between the index and simulated data for a few hypothetical fields are sufficient for such an analysis, although a more exhaustive comparison may be warranted in future studies.

Table 3. Soil series used in for generating simulated P loss data using the APLE model.

Soil series	HSG[1]	K[2]	T[3]
Johnsburg silt loam (Jo)	D	0.48	3.0
Ramsey loam (RaD)	D	0.22	1.0
Shelocta gravelly silt loam (ShB)	B	0.35	4.0
Zanesville silt loam (ZaB)	C	0.48	3.0

[1] Hydrologic soil group.
[2] RUSLE2 soil erodibility factor.
[3] Soil loss tolerance (tons/acre/yr).

RESULTS

The KY P index was first evaluated against simulated P loss data generated with the APLE model for a range of STP values. Increasing STP values resulted in increases in both the P index and the APLE simulated P loss data for each soil series (Figure 1). For the simulated data, P loss increased asymptotically with increasing STP due to how APLE treats particulate P loss as increasing nonlinearly with soil P. On the other hand, due to the exponential weighting used in the KY P index, the increase in index value with increasing STP is greatest at the highest STP value. The KY P index, as with many other state P indices, treats STP as a discrete rather than continuous variable; thus the index may underestimate the risk of P loss from soil for a given range in STP values. For instance, the index calculated the risk of P loss from soils with STP values ranging from 501 to 800 lbs/acre as being equivalent whereas simulated P loss values increased by 25 to 40% over this range of STP values depending on soil type, field slope, and crop type.

Increasing field slope increased both runoff and erosion as predicted by the SCS curve number method and RUSLE2, respectively. For each crop type and soil series, erosion rates as predicted by RUSLE2 increased linearly with increasing field slope from 1.5 to 9% but a greater increase in erosion rates when field slope increased from 9 to 13% was observed (Figure 2). For runoff, increasing field slope resulted in linear increases in runoff as calculated by the SCS curve number method using the slope modification method employed by the APEX model (Figure 2). Increasing field slope resulted in a near linear increase in simulated P loss data for all four soils simulated with tall fescue and winter wheat (Figure 3). With soils simulated with corn grain, however, increasing field slope from 9 to 13% resulted in a greater increase in simulated P loss than at lower slopes. For all soils and crop types, increasing field slope from 9 to 13% resulted in a greater increase in the P index than did increases at lower slopes.

Comparing the Shelocta (HSG B), Zanesville (HSG C), and Johnsburg (HSG D) soils showed that soils with greater runoff potential resulted in greater simulated P loss and P index values (Figures 1, 3), although differences between soils with different runoff potentials varied depending on STP and field slope for the simulated data whereas for the KY P index differences were independent of STP and field slope. For instance, the difference in simulated P loss between the Shelocta (HSG B) and Johnsburg (HSG D) soils when planted with winter wheat was 0.70 kg/ha for STP of 400 and 1.6 kg/ha for STP of 1000 lbs/acre (Figure 1C), yet the KY P index is weighted in such a way that the difference in index values between HSG B and D is 6 for any given STP value (Figure 1D). Similarly, for the corn simula-

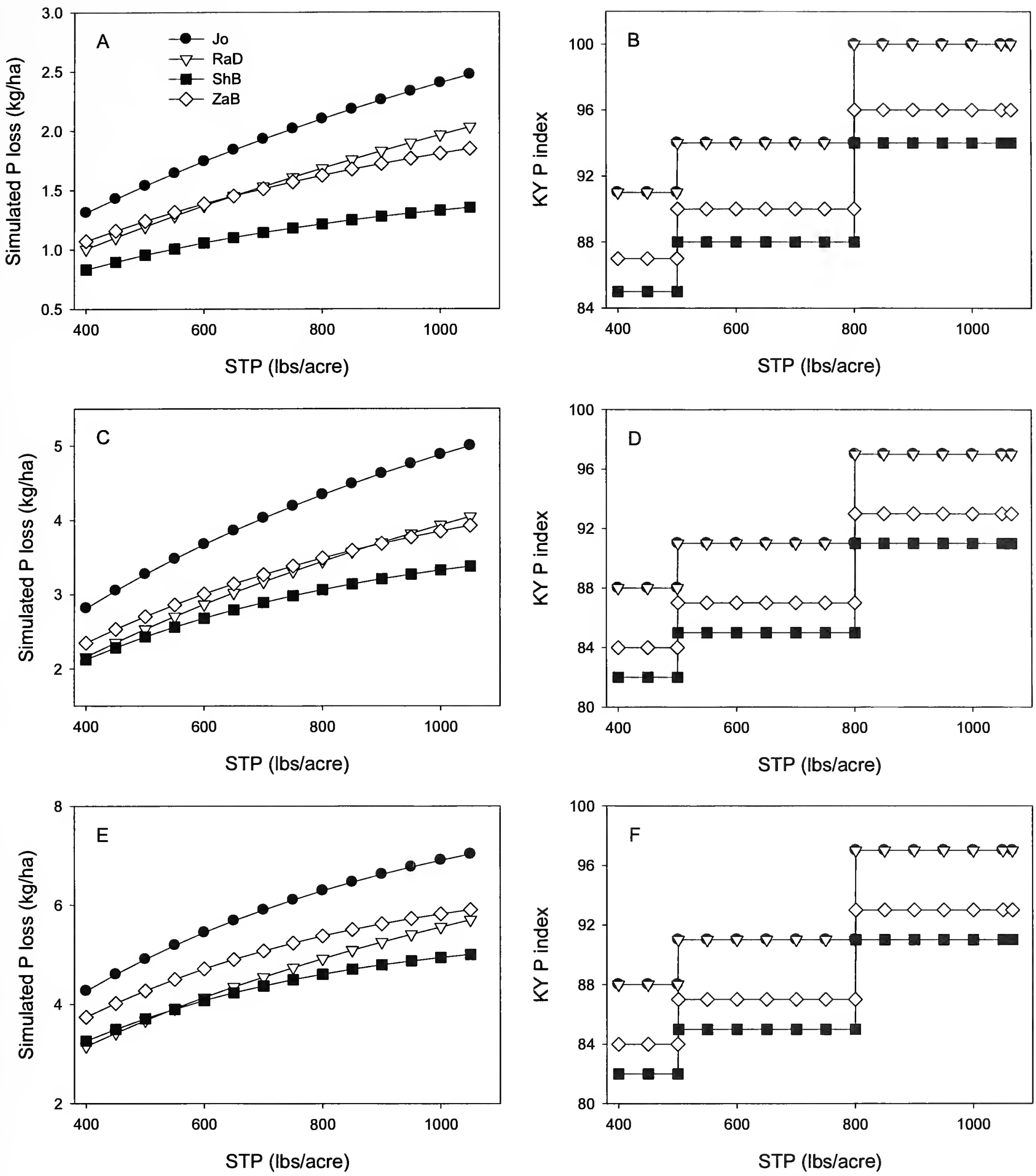

Figure 1. Effect of increasing soil test P (STP) on simulated P loss data (left panels) and the KY P index (right panels) for each soil series (Johnsburg (Jo), Ramsey (RaD), Shelocta (ShB), and Zanesville (ZaB) for the (A, B) forage hay, (C, D) winter wheat, and (E, F) corn grain simulations for a field slope of 3.5%. For these simulations vegetative buffer width, application method, and downstream distance were all assigned a risk rating of very high (8 points) whereas impaired watershed, application timing, and county location were all assigned a risk rating of low (1 point). Land cover rating was assigned a medium risk value (2 points) for the forage hay simulations whereas a low risk rating was assigned to the winter wheat and corn simulations.

tions the difference in simulated P loss between the Shelocta (HSG B) and Johnsburg (HSG D) soils was 1.1 kg/ha for a field slope of 1.5% and 3.7 kg/ha for a field slope of 13% (Figure 3E) while the difference in index values remained constant (Figure 3F).

While runoff from both the Johnsburg and Ramsey soils was the same due to both soils being classified as HSG D, RUSLE2 calculated erosion rates for the Ramsey soil 40 to 50% lower than the Johnsburg soil for each crop type (Figure 2). The reduced erosion rate for the Ramsey soil was due to the lower erodibility factor for this soil (0.22 compared with 0.48 for Johnsburg soil, Table 3). Soil erodibility is a function of soil texture, soil organic matter content, subsoil structure, and soil permeability and is an important factor controlling soil loss. This decrease in erosion explains why simulated P loss for the Ramsey soil was noticeably lower than the Johnsburg soil (Figures 1, 3). The KY P index, however, rated risk of P loss from these two soils as being equal because the KY P index does not account for soil erodibility (Figures 1, 3) and thus does not adequately capture the differences in risk between these two soils. To better represent risk of P loss by eroding soil will require incorporation of erosion rates into the KY P index; most state P indices currently use RUSLE or RUSLE2 to calculate erosion rates (Sharpley et al. 2003).

Analyzing data from all the simulations combined, a mild but significant correlation ($r = 0.29$, $P < 0.001$) was observed between the simulated data and index values (Figure 4). The correlation between simulated data and index values increased dramatically when data for each crop type were analyzed separately with r values of 0.78, 0.74 and 0.62 for the forage hay, wheat, and corn simulations, respectively. This further highlights the inability of the KY P index to account for differences in P loss risk among different crop rotations. Inclusion of erosion rates into the KY P index will likely increase its correlation with output from the APLE model.

DISCUSSION

The objective of any P index is to simply and accurately estimate the risk of P loss from the landscape. Although the P index is used in the majority of states to assess risk of P loss from agricultural fields, most state P indices have not been rigorously evaluated against measured P loss data to determine how well the index assigns risk—a major reason being the lack of field data available for such an analysis. Recognizing this, a Working Group of scientists within the Southern Extension-Research Activity Group 17 (SERA-17) recently recommended that P indices be evaluated against simulated P loss data using accepted P transport models when measured P loss data are unavailable (Sharpley et al. 2011). Veith et al. (2005) used this approach to evaluate the Pennsylvania P index by comparing index values with P loss values calculated with the SWAT model and observed good correlations between the P index and output from SWAT and concluded that the Pennsylvania P index was generally accurate. Comparing KY P index values with simulated P data generated with the APLE model for a handful of hypothetical fields with ranges in STP values, runoff potential, erosion rates, and field slopes, showed that index values were generally correlated with the simulated data. This analysis, however, also showed some important limitations with the index including how the different factors in the index are weighted and how erosion is accounted for in the index.

In addition to comparing the KY P index against output from a process-based model, the index can be further evaluated by assessing whether the formulation of the index is consistent with published research and whether the index accounts for all the importance source and transport factors expected to control P movement through the landscape in Kentucky. This includes P application method, timing, and amount; distance from P application to surface water; potential for P leaching through the subsurface; and formulation of the index.

The application of mineral fertilizer or animal manure to agricultural fields can result in significant increases in dissolved runoff P concentrations. Loss of P from applied fertilizers and manures will depend on application method, rate, and timing. While the KY P index accounts for both P application method and timing it does not include P application rate. Application method is accounted for in the KY P index by assigning the lowest value rating when P is injected into the soil and the highest value rating when P is surface applied and left unincorporated for more than 1 month. This approach is consistent with studies which have shown that incorporation of manure into the subsurface results in reduced dissolved runoff P concen-

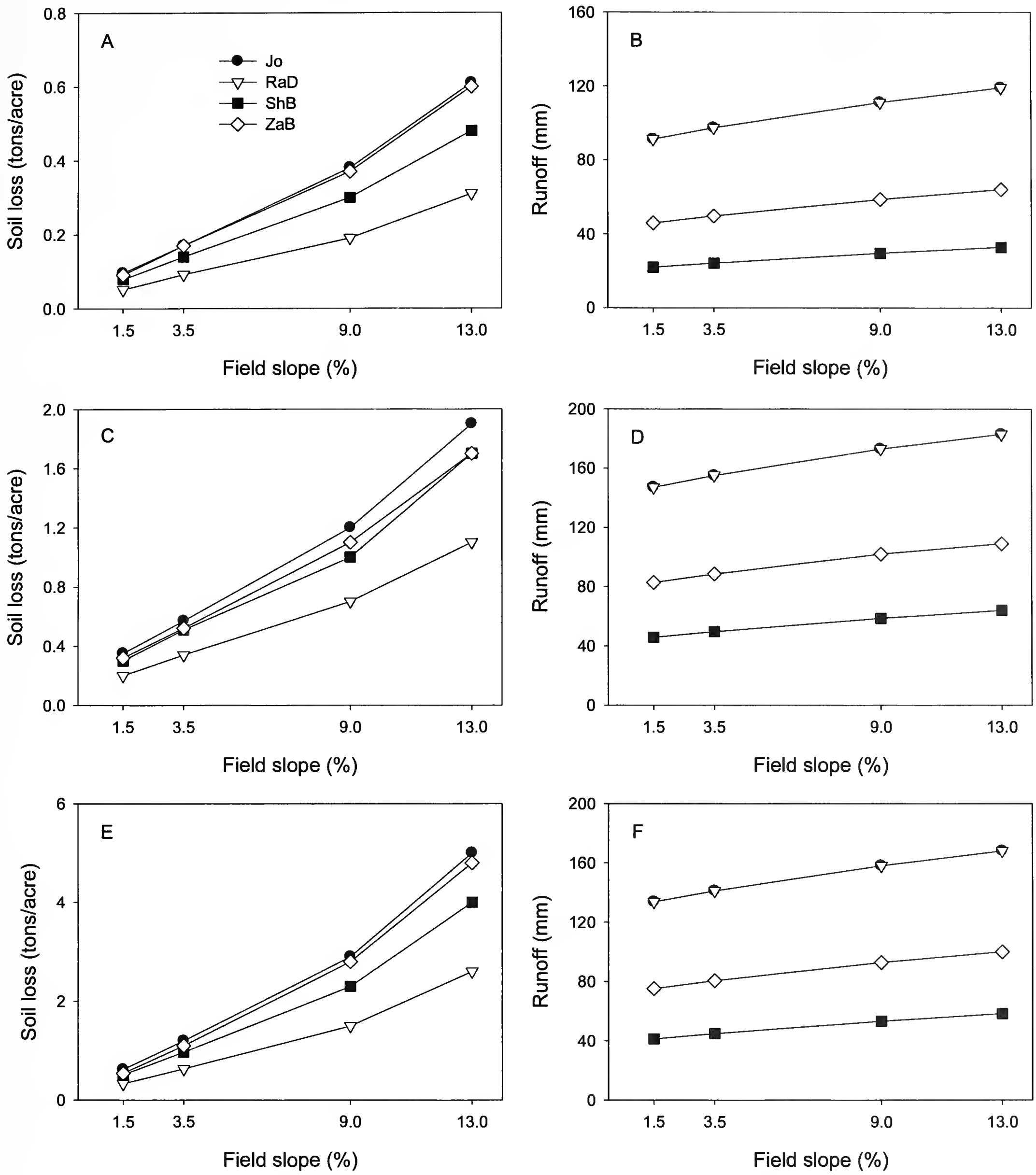

Figure 2. Relationship between field slope and RUSLE2-predicted erosion rates (left panels) and runoff predicted using the SCS curve number method modified for slope (right panels) for each soil for the (A, B) forage hay, (C, D) winter wheat, and (E, F) corn grain simulations.

trations compared with surface applications (Kleinman et al. 2002; Pote et al. 2003; Daverede et al. 2004; Torbert et al. 2005; Sistani et al. 2009; Sistani et al. 2010). A potential limitation with the index is that it does not allow for partial incorporation of P. That is, P is assumed to be either fully incorporated or remain completely on the surface. In developing the APLE model Vadas et al. (2009) assumed an inverse linear relationship between fraction of P incorporated and runoff P concentrations in their model. Further studies are needed, however, to determine the relationship between P loss and fraction of P incorporated into the soil. Another potential limitation with the index is

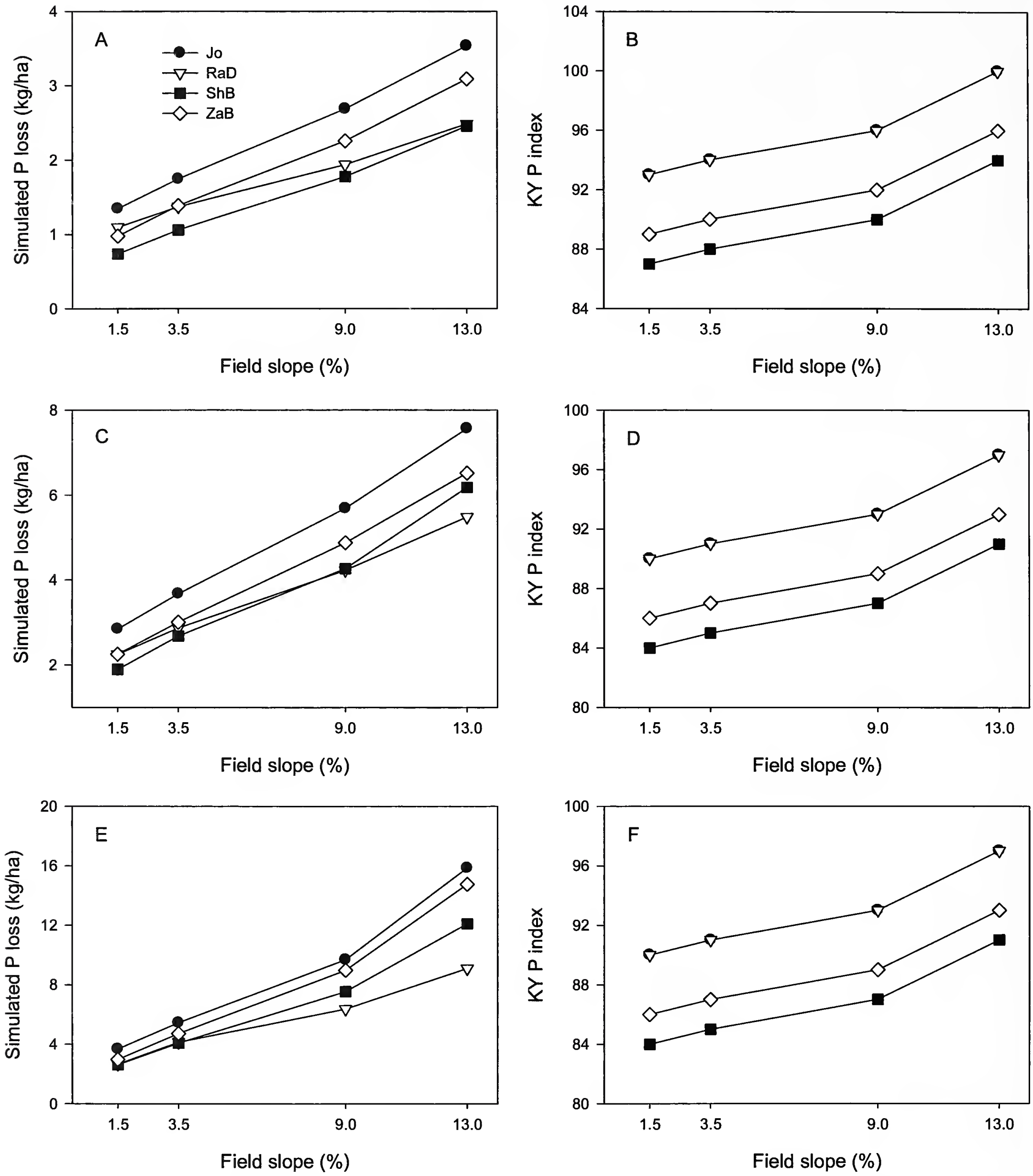

Figure 3. Effect of field slope on simulated P loss data (left panels) and the KY P index (right panels) for each soil series soil for the (A, B) forage hay, (C, D) winter wheat, and (E, F) corn grain simulations for STP value of 600 lbs/acre. For these simulations vegetative buffer width, application method, and downstream distance were all assigned a risk rating of very high (8 points) whereas impaired watershed, application timing, and county location were all assigned a risk rating of low (1 point). Land cover rating was assigned a medium risk value (2 points) for the forage hay whereas a low risk rating was assigned to the winter wheat and corn simulations.

that it does not account for the possible increase in particulate P loss that may occur when P is incorporated into the soil due to increased soil erosion (Andraski et al. 1985; Cox and Hendricks 2000). Incorporation of erosion rates into the index would help address this limitation.

Application timing is another important factor to include when assessing risk of P loss from applied P sources. When P applications

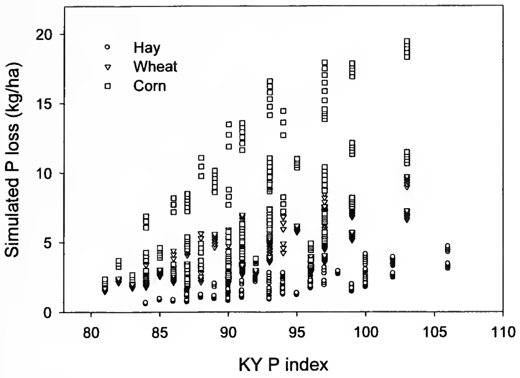

Figure 4. Relationship between simulated P loss data and the KY P index. Results show that the KY P index is in general directionally consistent with the simulated P loss data with a correlation coefficient of 0.29 ($P < 0.001$). However, a large amount of scatter exists highlighting potential limitations with the index.

are made during periods when runoff-generating precipitation events are common, risk of P loss will be greater. The KY P index accounts for application timing by assigning risk based on the month of planned P application. Low values are assigned to summer months when runoff is generally low due to reduced precipitation and increased evapotranspiration and high values are assigned to winter months when precipitation is greater and evapotranspiration is low. Furthermore, plant nutrient uptake will be lowest during the winter season thereby also increasing risk of P loss.

In addition to runoff volume, the time interval between P application and the next runoff event has been shown to greatly affect P loss for surface applied P, with P loss decreasing with increasing time between application and runoff event (Schroeder et al. 2004; Sharpley 1997; Sistani et al. 2009); for incorporated P sources, however, timing between P application and runoff may not be as important (Sistani et al. 2009). Because the time interval between P application and a runoff event is impossible to account for in a P index, it is important that best management practices are followed that prevent P application on fields during or immediately prior to expected precipitation events. One approach would be to develop a Web-based program in which a producer enters the geographic location and the program calculates whether P application can occur on a given day based on recent and forecasted weather conditions.

Phosphorus application rate is another important factor controlling risk of P loss with increasing fertilizer or manure application rates resulting in increased P in runoff, as well as elevated runoff P concentrations for extended periods of time following application (Schroeder et al. 2004). Indeed, recently applied P can override soil P as the dominant factor controlling runoff P concentrations (Kleinman et al. 2002; DeLaune et al. 2004a), yet the KY P index is one of only a few P indices that does not include P application rate in its calculations (Sharpley et al. 2003). Therefore, consideration should be given to including P application rate in the KY P index. Because runoff P loss from applied fertilizers and manures varies depending on the solubility of the P source (Kleinman et al. 2002; Shigaki et al. 2006), a weighting factor should be included to account for the relative solubility of the applied P source (Leytem et al. 2004; Elliot et al. 2006; Vadas et al. 2009). Inclusion of such a factor also can be used to evaluate the impact that manure management strategies such as addition of P-sorbing amendments (Moore et al. 2000; DeLaune et al. 2004a) or manipulation of animal diets (Wu et al. 2000; DeLaune et al. 2004a) has on P loss risk assessment and thus allowable manure application rates.

Another important factor controlling the potential of applied P to adversely affect a water body is the distance between the water body and location where nutrient application occurred. The KY P index ranks fields adjacent to water bodies as very high risk, those within 0 to 50 ft as high risk, 50 to 150 ft as medium risk, and those 150 feet or greater as low risk of P loss. Because the impact of distance between field and receiving water body on P transport will depend on numerous factors including field slope and land cover, it is difficult to determine what distance represents a reasonable estimate of high risk of P loss and what distance represents a low risk of P loss. Based on observations from a small watershed in Pennsylvania, Gburek et al. (2000) assigned a risk of very high to fields within 150 ft of a receiving water body and low risk to fields greater than 500 ft from a receiving water body in the Pennsylvania P index. These distances are much greater than the distances used for calculating risk in the KY P index. Research must be conducted on agricultural fields in KY to obtain a better understanding of how transport distance affects risk of P loss to receiving water bodies.

The KY P index, along with the majority of state P indices, does not consider the risk of P loss through leaching. This is primarily due to the long-held assumption that P is so strongly sorbed to sediments that its translocation through the subsurface is minimal and therefore poses minimal risk to surface waters. This assumption, however, may not be true in soils with low P sorption capacities, soils with high infiltration rates, and/or shallow soils. For instance, in tile-drained fields where leaching distance is short and drainage water is diverted directly to nearby surface waters, P loads from leaching can be substantial (Sims et al. 1998). Moreover, in well-developed karst areas where soils are thin and groundwater moves primarily through large underground conduits, the retention of P may be minimal. Given the presence of both tile-drained fields and shallow soils in well developed karst areas in Kentucky, consideration should be given to including risk of P loss by subsurface leaching in the KY P index. Pennsylvania (Weld et al. 2002) and North Carolina (N.C. PLAT Committee 2005) are two of several states that have included risk of leaching loss in their P index, and these indices can serve as examples.

Another important factor to consider when evaluating a P index is how the final index value is calculated. The KY P index follows the formulation of the original P index in that the final index value is calculated as the sum of the rated transport and source factors, with each weighted factor treated separately (Lemunyon and Gilbert 1993). Gburek et al. (1998) demonstrated that a multiplicative formulation, where a P index is calculated as the product of the summed transport and source factors, better captures the role that transport plays on P loss. Incorporating this multiplicative approach into the Pennsylvania P index, the authors found improvements in the index's ability to predict P loss (Gburek et al. 2000), and as a result, many states have adopted the multiplicative formulation for calculating their index (Sharpley et al. 2003). A third formulation used in a handful of states sums P loss from each individual component contributing to P loss. In this formulation, each component is calculated as the product of both transport and source factors and best reflects the processes governing P transport in the environment and is consistent with how P loss is calculated in process-based P loss models.

CONCLUSIONS

The objective of this paper was to critically evaluate the KY P index to identify where the index may need revising and to encourage discussion and research for updating it. Given the lack of available P loss data, this evaluation relied on comparing results from the KY P index with P loss data generated using established models such as APLE, RUSLE2, and the SCS curve number method. While this analysis was limited to a few hypothetical fields and field and management conditions, this analysis did provide valuable insight into some potential limitations with the index – primarily the neglect of important factors known to affect P loss (i.e., soil erosion and P application rates) and in how the different factors in the index are weighted. To reduce the amount of P that is exported from agricultural fields to waterways within Kentucky, effort and resources should be devoted to updating the KY P index as well as developing long-term monitoring sites where the index and process-based models can be evaluated against measured P loss data. When considering modifications to the KY P index, however, it is important that environmental concerns be balanced with considerations regarding the potential economic impact to landowners and producers.

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New County Distribution Records of Dragonflies and Damselflies (Odonata) in Florida, Kentucky, and Tennessee

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ABSTRACT

A total of 30 new odonate county distribution records are presented for counties in Florida, Kentucky, and Tennessee. The known odonate fauna of Madison County, Kentucky, is increased from 16 to 27 species and the fauna of Claiborne County, Tennessee, is increased from 18 to 27 species. Libellulidae and Coenagrionidae species accounted for the majority of the new records, 15 and 7, respectively.
KEY WORDS: Odonata, Central Kentucky Wildlife Management Area, Blue Grass Army Depot, Powell River, Lake Griffin, Florida, Tennessee, county records

INTRODUCTION

Annotated lists of the odonate fauna of Florida, Kentucky, and Tennessee are published in Dunkle (1992), Resener (1970), and Trogdon (1961), respectively. These lists were updated by Donnelly (2004a, 2004b, 2004c) who compiled all of the known Odonata distribution records for North America. Currently, 153 odonate species are recorded from Kentucky, 154 species from Tennessee, and 170 species from Florida. These diverse faunas contain 34–37% of the odonate species known from the continental United States (Abbott 2007). Yet, despite the advanced listings available for these three southeastern states, disproportionate sampling intensity has limited our knowledge of the faunal compositions within each state. Donnelly (2004a, 2004b, 2004c) and Abbott (2007) reported that more than 50 percent of Kentucky's and Tennessee's counties have records of 20 or fewer odonate species; 31% of Kentucky's counties and 26% of Tennessee's counties have records of 10 or fewer species.

METHODS AND MATERIALS

In the course of the first author's study of the odonate fauna of the upper Rockcastle River system in Kentucky (McMurray and Schuster 2009), opportunities were presented for additional collections to be made within the Commonwealth. During this time collections were also made at locations in Claiborne County, Tennessee, and Lake County, Florida. A total of 30 new odonate county distribution records were accumulated from 2002 to 2009.

Adult odonates were collected from a variety of habitats (small and medium sized streams, wetlands, ponds, and lakes) with a large (45 cm wide) aerial net (Bioquip Tropics Net, #7324). Collected odonates were put into glassine envelopes and submerged in acetone for 8–24 hours, depending on the size of the specimen. After drying, specimens were stored in clear cellophane envelopes with pertinent collection information typed on a 3″ × 5″ index card (Needham et al. 2000).

Identifications of adult odonates were made using Westfall and May (1996), Needham et al. (2000), and Glotzhober and McShaffrey (2002). Photographs of potential county records with complete collection dates were submitted to the Odonata Central website (www.odonatacentral.org) for verification. Odonata Central record numbers (OC #) are given with those records listed below. Specimens with incomplete collection dates were sent to Ellis Laudermilk (Kentucky State Nature Preserve Commission, Frankfort, Kentucky) for verification. All specimens are currently held in the personal collection of the first author. Collector's initials correspond to those of the first author and Chris Distel (CD), Quinten Tolliver (QT), Rusty Johns (RJ), and Sandra Bowman (SB).

RESULTS

The 30 new county records were distributed across seven odonate families and included a

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total of 24 species. Libellulidae was the most well represented family with 11 species accounting for 15 of the new records. Coenagrionidae was the next most abundant family represented by five species and seven new records.

Eleven new species were documented for Madison County, Kentucky (69% increase from 16 to 27 records), and nine new species were documented for Claiborne County, Tennessee (50% increase from 18 to 27 records) (Abbott 2007). Four odonate species were added to the known fauna of Rowan County, while one species was added to the known faunas of Laurel, Rockcastle, and Metcalfe counties, Kentucky (Abbott 2007; McMurray and Schuster 2009). The fauna of Lake County, Florida, was increased by three species (Abbott 2007).

The additions to the known distributions of odonate species in the southern United States suggest that more intensive collection efforts are needed in certain counties that have previously been sparsely sampled. The new records document a significant increase in species composition for Madison County, Kentucky (69% increase), and Claiborne County, Tennessee (50% increase) compared with the previously known odonate faunas. Increased effort, even in well studied areas, has the potential to reveal cryptic species and additional species with limited ranges.

Annotated List of New Odonata Records

Kentucky

Madison County: pond at Central Kentucky Wildlife Management Area; 11.3 km northeast of Berea (37.631295 N, −84.192352 W).

Coenagrionidae

Argia fumipennis violacea (Burmeister) (Variable Dancer): 1♂, 2003, QT.

Argia sedula (Hagen) (Blue-ringed Dancer): 2♂♂, 2003, QT.

Enallagma basidens Calvert (Double-striped Bluet): 3♂♂, 2003, QT.

Lestidae

Lestes vigilax Hagen in Selys (Swamp Spreadwing): 3♂♂, 9 August 2003, PDM, OC #316002.

Libellulidae

Libellula incesta Hagen (Slaty Skimmer): 1♂, 2003, QT.

Pachydiplax longipennis (Burmeister) (Blue Dasher): 2♂♂ 1♀, 9 August 2003, PDM, OC #316001.

Madison County: pond at Blue Grass Army Depot; 8.3 km southeast of Richmond (37.699578 N, −84.223251 W)

Coenagrionidae

Enallagma civile (Hagen) (Familiar Bluet): 1♂, 2002, CD.

Lestidae

Lestes rectangularis Say (Slender Spreadwing): 1♀, 2002, CD.

Libellulidae

Plathemis lydia (Drury) (Common Whitetail): 1♂, 2002, CD.

Sympetrum vicinum (Hagen) (Autumn Meadowhawk): 1♂, 2002, CD.

Tramea lacerata Hagen (Black Saddlebags): 2♂♂, 2002, CD.

Metcalfe County: East Fork Little Barren River; SR 544 bridge crossing in East Fork, 10.8 km northeast of Edmonton (37.058122 N, −85.553455 W).

Coenagrionidae

Enallagma basidens Calvert: 1♂ 1♀, 7 June 2002, PDM, OC #316008.

Rockcastle County: SR 490, 0.8 km east of Livingston (37.295154 N, −84.209733 W).

Petaluridae

Tachopteryx thoreyi (Hagen in Selys) (Gray Petaltail): 1♂, 15 July 2003, PDM, OC #316010.

Laurel County: Sinking Creek; Dog School Branch Road bridge crossing, 1.32 km southeast of Bunch (37.09736 N, −84.225569 W).

Gomphidae

Progomphus obscurus (Rambur) (Common Sanddragon): 3♂♂, 29 July 2002, PDM, OC #316014.

Rowan County, Scott Creek Wetlands; northeast of KY 801 at Cogswell, 10.1 km south-southeast of Morehead (38.098801 N, −83.488154 W).

Libellulidae

Celithemis elisa (Hagen) (Calico Pennant): 1♂, 12 August 2002, PDM, OC #316005.

Erythemis simplicicollis (Say) (Common Pondhawk): 1♂ 1♀, 12 August 2002, PDM, OC #316003.

Libellula cyanea Fabricius (Spangled Skimmer): 1♂, 12 August 2002, PDM, OC #316004.

Tramea lacerata Hagen: 1♂ 1♀, 12 August 2002, PDM, OC #316006.

Tennessee

Claiborne County: Powell River; end of Grantham Ford Road, 0.8 km downstream US 25E bridge, 4.2 km south of Harrogate (36.543329 N, −83.640053 W)

Calopterygidae

Hetaerina americana (Fabricius) (American Rubyspot): 1♂, 5 July 2003, PDM; 1♂ 3♀♀, 21 July 2006, PDM, OC #315974.

Claiborne County: Blair Creek; Vancel Road bridge crossing, 6.7 km south of Harrogate (36.520294 N, −83.636405 W)

Cordulegastridae

Cordulegaster maculata Selys (Twin-spotted Spiketail): 1♀, 13 May 2007, PDM, OC #315975.

Gomphidae

Hagenius brevistylus Selys (Dragonhunter): 1♂, 3 July 2009, PDM, OC #315976.

Claiborne County: pond at P. McMurray farm; 6 km south of Harrogate (36.525984 N, −83.638358 W)

Coenagrionidae

Enallagma civile (Hagen): 1♂, 23 August 2004, PDM; 1♂, 10 May 2003, PDM, OC #316002.

Ischnura posita (Hagen) (Fragile Forktail): 1♂ 1♀, 23 August 2004; 2♂♂ 1♀, 2 September 2007, PDM, OC #316023.

Libellulidae

Pachydiplax longipennis (Burmeister): 1♂ 1♀, 23 August 2004, PDM, OC #316019.

Perithemis tenera (Say) (Eastern Amberwing): 1♂, 23 August 2004, PDM, OC #316017.

Plathemis lydia (Drury): 1♂, 22 June 2002, PDM; 3♂♂ 2♀, 10 May 2003, PDM; 2♂♂, 23 August 2004, PDM; 1♂, 18 May 2006, PDM, OC #316018.

Tramea lacerata Hagen: 1♂, 5 July 2003, PDM, OC #316020.

Florida

Lake County: Lake Griffin; Lakeside Drive, Lakeside Village Retirement Community, Leesburg (28.828687 N, −81.837351 W)

Gomphidae

Gomphus dilatatus (Rambur) (Blackwater Clubtail): 1♂, 2 April 2005, SB, OC #315965.

Libellulidae

Miathyria marcella (Selys in Sagra) (Hyacinth Glider): 1♀, 30 August 2002, SB, OC #315964.

Pantala flavescens (Fabricius) (Wandering Glider): 1♂ 1♀, 4 August 2002, PDM; 1♀, 11 August 2002, SB; 1♂, 14 September 2002, RJ, OC #315962.

ACKNOWLEDGEMENTS

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NOTE

Assessing the moth community at John James Audubon State Park, Kentucky—The importance of nocturnal lepidopterans to terrestrial communities has been well-documented. Moths provide food for birds and bats (Johnson et al. 2007; Burles et al. 2008) and are significant plant pollinators (Campbell 1985; Petterson (1991); Herrera 1995; Wiggam and Ferguson 2005) with the ability to alter plant communities and the organisms that interact with them. There are approximately 273 described species of moths present in the state of Kentucky (Marcus et al. 2007).

The objective of this study was to gather the first qualitative data on the moth community at the John James Audubon State Park, Kentucky (JJASP). This objective is in line with those set by personnel at JJASP, "To finish inventorying the preserve and complete a species list for mammals, herpetiles, birds, and vascular plants and to develop a list for insects, fungi, mosses, lichens, etc. as expertise becomes available" (Julie McDonald, Park Naturalist, John James Audubon State Park, pers. comm., May 2010). To date, such information on moths does not exist, and a survey of the biodiversity of the Park is desirable from an educational perspective as well as from a baseline scientific standpoint.

Established in 1934, JJASP comprises approximately 293 ha located along the Ohio River in Henderson County, Kentucky. In 1979, approximately 132 ha were designated as a nature preserve. An 8.9 km trail system is included within the park, as well as several Civilian Conservation Corps structures that date back to the 1930s. Habitat alterations outside the park include improved roads, power lines, interpretive structures, and trails, making JJASP an "island" within a matrix of otherwise unsuitable habitat for many species. The habitat at JJASP is classified as a deep soil mesophytic forest (Evans 1991).

The study was conducted from May 16–August 20, 2008, and data were collected approximately once every two weeks. Six study plots (Figure 1) were utilized for June 5, June 20, July 1, and July 16 collections, and 2 plots were used for the August 8 and August 20 collections because of equipment limitations. Study locations were chosen to maximize habitat types within the park. Trapping did not occur when excessive rain or windy conditions were predicted.

One black light trap (BioQuip Products, Rancho Dominguez, CA) was placed at each of the study sites, usually between 2:00 P.M. and 4:00 P.M. the day before each collection was scheduled. The 12 volt car batteries used to power the traps were sufficient to ensure that they would be effective throughout the night. Traps remained on overnight until each site was revisited after daybreak

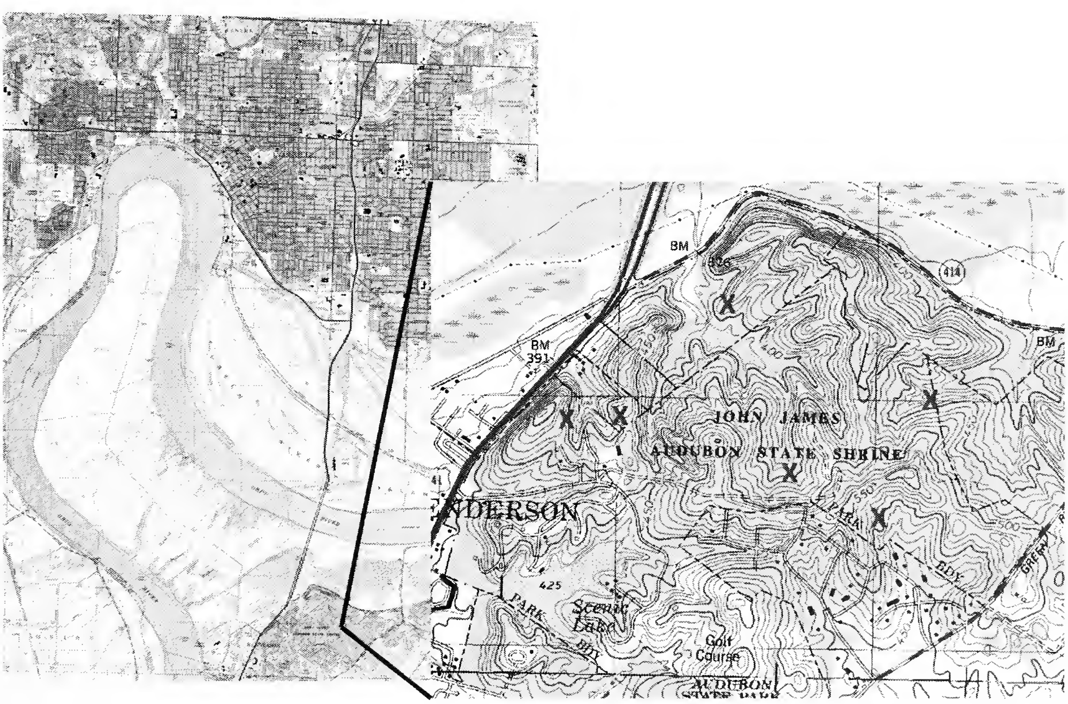

Figure 1. Map of the study sites used for black light trapping at John James Audubon State Park, May 16–August 20, 2008.

Table 1. Summary of the species collected in blacklight traps at John James Audubon State park May–August 2008.

Family	Species	Family	Species
Arctiidae	*Apantesis vittata* (F.)	Noctuidae	*Isogona tenuis* (Grt.)
Arctiidae	*Cisseps fulvicollis* (Hbn.)	Noctuidae	*Lacinipolia lorea* (Gn.)
Arctiidae	*Holomelina opella* (Grt.)	Noctuidae	*Leucania inermins* (Fbs.)
Arctiidae	*Hypoprepia miniata* (Kby.)	Noctuidae	*Leuconycta diphteroides* (Gn.)
Arctiidae	*Spilosoma latipennis* (Stretch.)	Noctuidae	*Noctua pronuba* (L.)
Apatelodidae	*Apatelodes torrefacta* (J.E. Sm.)	Noctuidae	*Panopoda rufimargo* (Hbn.)
Apatelodidae	*Olceclostera angelica* (Grt.)	Noctuidae	*Peridea basitriens* (Wlk.)
Elachistidae	*Antaeotricha schlaeeri* (Zell.)	Noctuidae	*Peridea* sp.
Geometridae	*Anacamptodes ephyraria* (Wlk.)	Noctuidae	*Plusiodona compressipalpis* (Gn.)
Geometridae	*Epimecis hortaria* (F.)	Noctuidae	*Polygrammate hebraeicum* (Hbn.)
Geometridae	*Eubaphe mendica* (Wlk.)	Noctuidae	*Protolampra brunneicolis* (Grt.)
Geometridae	*Euchlaena amoenaria* (Gn.)	Noctuidae	*Pseudaletia unipuncta* (Haw.)
Geometridae	*Euchlaena irraria* (B & McD.)	Noctuidae	*Pyrrharctia isabela* (J.E. Sm.)
Geometridae	*Eulithis diversilineata* (Hbn.)	Noctuidae	*Spiloloma lunilinea* (Grt.)
Geometridae	*Eutrapela clemataria* (J.E. Sm.)	Noctuidae	*Zale lunata* (Dru.)
Geometridae	*Itame pustularia* (Gn.)	Notodontidae	*Datana drexelii* (Hy. Edw.)
Geometridae	*Lomographa vestaliata* (Gn.)	Notodontidae	*Nadata gibbosa* (J.E. & Sm.)
Geometridae	*Mellilla xanthometata* (Wlk.)	Notodontidae	*Datana perspicua* (Grt. & Rob.)
Geometridae	*Metarranthis duaria* (Gn.)	Oecophoridae	*Ethmia zelleriella* (Cham.)
Geometridae	*Petrophora divisata* (Hbn.)	Pyralidae	*Desmia funeralis* (Hbn.)
Geometridae	*Plagodis fervidaria* (H.-S.)	Pyralidae	*Desmia maculalis* (Westwood.)
Geometridae	*Prochoerodes transversata* (Dru.)	Pyralidae	*Diaphania nitidalis* (Stoll.)
Geometridae	*Semiothisa eremiata* (Gn.)	Pyralidae	*Herculia infimbrialis* (Dyar.)
Geometridae	*Semiothisa ocellinata* (Gn.)	Pyralidae	*Herculia olinalis* (Gn.)
Lasiocampidae	*Malacosoma americanum* (F.)	Pyralidae	*Pantographa limata* (Grt. &Rob.)
Noctuidae	*Acronicta haesitata* (Grt.)	Saturniidae	*Actias luna* (L.)
Noctuidae	*Acronicta spinigera* (Gn.)	Saturniidae	*Callosamia angulifera* (Wlk.)
Noctuidae	*Agrotis ipsilon* (Hufn.)	Saturniidae	*Citheronia regalis* (F.)
Noctuidae	*Anagrapha falcifera* (Kby.)	Saturniidae	*Sphingicampa bisecta* (Lint.)
Noctuidae	*Callopistria mollissima* (Gn.)	Sphingidae	*Ceratomia amyntor* (Geyer.)
Noctuidae	*Catocala maestosa* (Hulst.)	Sphingidae	*Ceratomia catalpae* (Bvd.)
Noctuidae	*Catocala* sp.	Sphingidae	*Ceratomia undulosa* (Wlk.)
Noctuidae	*Eudryas grata* (F.)	Sphingidae	*Darapsa myron* (Cram.)
Noctuidae	*Euplexia benesimilis* (Mc.D.)	Sphingidae	*Laothoe juglandis* (J.E. Sm.)
Noctuidae	*Euxoa perpolita* (Morr.)	Sphingidae	*Paonias astylus* (Dru.)
Noctuidae	*Halysidota tessellaris* (J.E. Sm.)	Sphingidae	*Sphecodina abbottii* (Swainson)
Noctuidae	*Haploa clymene* (Brown)	Yponomeutidae	*Atteva punctella* (Cram.)
Noctuidae	*Hypsoropha monilis* (F.)		

the following morning. Commercially available "No-pest Strips" containing dichlorvos (2,2-dichlorovinyl dimethyl phosphate; DDVP) were used as a killing agent, and all specimens were returned to the lab and frozen until sorting and identification could take place.

Specimens were identified to genus and species levels where possible, although the condition of some specimens precluded identification beyond family. Similarly, it was not possible to quantify species abundance, because many of the specimens were in poor condition. When reliable identification to genus and species was possible, individual specimens were pinned and placed into a reference collection at Kentucky Wesleyan College.

Covell and Gibson (2008) reported a total of 2493 species of butterflies and moths from the state of Kentucky. While this updated figure expands on the 2388, 2423, and 2452 species previously recorded by Covell Jr. (1999), Covell Jr. et al. (2000), and Gibson and Covell Jr. (2006), respectively, these authors maintain that more species likely await identification as new habitats are surveyed. A total of 75 species representing 12 families was identified during the study (Table 1). This likely is a minimum estimate of the species present in the park but gives a starting point for an inventory. The number of species collected represents approximately 28.2% of the species known from Kentucky (Marcus et al. 2007).

With few exceptions (notably *Cisseps fulvicollis* Hbn., *Anacamptodes ephyraria* Wlk., *Euchlaena amoenaria* Gn., *Semiothisa ocellinata* Gn., *Catocala maestosa* Hulst., *Plusiodona compressipalpis* Gn., *Pseudaletia unipuncta* Haw., *Zale lunata* Dru., *Herculia olinalis* Gn., which have been reported in Henderson Co., OH but not in JJASP), most of the species collected in this study have not been recorded either in JJASP or in Henderson Co., OH (Covell Jr. 1999; Covell and Gibson 2008, and Gibson and Covell 2006). The most common species collected in May–August at JJASP were the oval-based prominent (*Peridea basitriens* Wlk.), brown-collared dart (*Protolam-*

pra brunneicolis Grt.), armyworm moth (*Pseudaletia unipuncta* Haw.), banded tussock moth (*Halysidota tessellaris* J.E. Sm.), white-dotted prominent (*Nadata gibbosa* J.E. Sm.), curved-toothed geometer (*Eutrapela clemataria* J.E. Sm.), large maple spanworm (*Prochoerodes transversata* Dru.), scarlet-winged lichen moth (*Hypoprepia miniata* Kby.), pink-legged tiger moth (*Spilosoma latipennis* Stretch.), and Ailanthus webworm moth (*Atteva punctella* Cram.). One invasive species, the European underwing moth (*Noctua pronuba* L.) was also collected on two occasions.

We thank Kentucky Wesleyan College for the funding to conduct this study and Dr. Andrew Storer, School of Forest Resources, Michigan Technological University, for the temporary use of several blacklight traps. We thank JJASP staff for permission to conduct this study at the Park and their cooperation with practical details throughout the duration of the project. Finally, we thank Jack and Marilyn Watson for their logistical support in making this project happen.

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Mountains. University of Northwestern South Dakota Press, Utopia.

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EDITOR'S COMMENT

The Journal of the Kentucky Academy of Science – what it is and is not.

D. S. White, Editor

As of Volume 72 (2011), the Academy is searching for an Editor to take over my role. It has been my distinct pleasure to have served as Editor for six years. During that time, I have been assisted by nearly 100 external reviewers, a very capable Executive Director (Jeanne Harris), indexer Ralph Thompson, and the great staff of Allen Press. With my tenure ending, I am taking this opportunity to provide some historical perspective on the Journal and to address some of the questions I've been asked as Editor. I make no attempt here to restate the wonderful and detailed history of the Academy provided by Ted George (1993) but instead to give my view through the eyes of an editor. Initially called the Transactions of the Kentucky Academy of Science, the name was changed in 1998 (Volume 59) to the Journal of the Kentucky Academy of Science, thus for simplicity, I simply will call it the Journal.

All back issues of the Journal have been scanned (thanks to the staff and students of the Hancock Biological Station) and now reside on the Academy website (www.kyscience.org). Volumes 1–66 are available to the general public. Volumes 67–71 are available to members only. The website also contains information on Academy membership, instructions for authors, etc.

The Journal has had many editors over the 71 volumes that span the 94 year history. I have been honored to be in their company. The first was Willard Rouse Jillison (Volume 1, 1914–1923) followed by A. M. Peter and Ethel V. T. Caswell (1924–1937), A. M. Peter (1938–1939), Charles Hire (1941), John Kuiper (1942–1944), Harlow Bishop (1945), M. C. Brockman and David R. Lincicome (1946–1947), William Clay and M. C. Brockman (1948–1950), William Clay (1950–1956), Gerald A. Cole (1957–1958), Roger Barbour (1959–1963), Raymond Hampton (1964–1967), William Wagner (1968–1973), Louis Krumholtz (1974–1980), Branley Branson (1981–1995), John W. Thieret (1996–2005 except for one issue in 2002 that was edited by Raymond Sicard), and David White (2006 to the present. These dates may differ from George (2003) as I have listed the Journal Volume years rather than terms of office.

Each editor has had distinct challenges and has added to the evolution of the Journal. The early years were devoted primarily to Academy business along with transcripts of abstracts or presentations made at the meetings. Minutes of the annual Governing Board meetings still remain a component of each Volume. Volume 9 (1941) saw the beginnings of the evolution into a modern scientific publication, and the Journal went from multiyear to a quarterly format. Each article was a true publication unto itself. Shorter scientific Notes were added in 1946. Under Bill Clay's direction, the Journal achieved it present look in 1948. Through 1974, the Journal had been published locally, primarily through the University of Kentucky Press. Louis Krumholz took the Journal to Allen Press in 1974, and although it may be coincidental, the number of articles per issue increased dramatically. Volume 1 covered the first 10 years of the Academy. Volumes 2–8 each contained two years of Academy business. Volumes 9–56 contained from one to four issues. The present day format of two issues, one spring and one fall, began with Volume 57 in 1996.

One challenge an editor faces with any academy of science journal is the diversity of disciplines that is contained in the membership and thus in the articles submitted. Within the larger divisions of biological, physical, and social sciences are many fields ranging from Agriculture to Chemistry to Astronomy to Zoology. Building a reliable list of reviewers is critical to maintaining scientific rigor, and it must be a long list.

An added complication is the number of submissions that are hard to fit into any one field of science; however, you are, or become, what you publish – or what you are perceived to publish. A review of approximately 850 articles (excluding Notes) from 1941 onward produced a good overview of the Academy during the past 70 years. Articles could be more or less placed in 21 categories provided that some lumping was done. Zoology leads the way with 45% of the articles followed by Botany (21%), Chemistry (11%), Ecosystem/Environmental Science (4%), Medical Sciences (4%), Agriculture (4%), Geology (2%), and Physics (1%). The remaining 8% covered a broad array of topics from Education to Computer Science to one manuscript on meter sticks. From 1941 to 1958, Chemistry articles outnumbered both Zoology and Botany. The number of Chemistry articles has declined steadily since the 1960s while Zoology has increased. The number of Botany articles has remained relatively constant. Ecosystem/Environmental Sciences articles emerged in the late 1960s and have remained fairly constant at 1–2 per year. Have the specializations of the editors had an influence? Potentially yes, but there appear to be no correlations. There has been a preponderance of editors with aquatic backgrounds but no observable trends toward water related articles. If there is a message here, the range of scientific disciplines submitting articles to the Journal has slowly increased, and I would expect that trend to continue; however, Zoology and Botany will carry on as the mainstays.

Some FAQs:

How widely is the Journal indexed? Historically, indexing of the Journal articles has been spotty. Hill and Madarash (2003) provided a detailed description of the up and downs through 2002. The Journal presently is indexed in BioOne, Cambridge Scientific Abstracts, State Academies of Science Abstracts, Selected Water Resource Abstracts, U.S. Fish and Wildlife Service, the Zoological Record, etc. Some of the latter services are restricted to specific subjects and not entire issues or volumes.

Who can publish in the Journal? I often have been asked if one has to be a member of the Academy to publish in the Journal. Do I have to live in Kentucky? Do articles have to be about something in Kentucky? The answer to each of these is no. Anyone can submit an article to the Journal as long as the subject matter falls within the realms of biological, physical, or social sciences embraced by the Academy. There is no requirement that the author(s) has to be a Kentucky resident or a KAS member. I would estimate that about a third of authors do not or no longer live in Kentucky. As to the question about being Kentucky related subjects, there are no hard and fast rules. Most states have an "academy of science" and usually associated "journals" that function similarly to ours. For example, many Agriculture, Botany, Sociology, and Zoology articles often have a regional focus on people, crops, ecosystems, distributions, life histories, etc. that might not be appropriate for national journals. Other articles (e.g., Astronomy, Chemistry, Physics) may have wider focuses but still are applicable to Kentucky. Because the Journal is widely indexed, even the more locally focused articles wind up having a national presence. If an author is not sure about the appropriateness of the article, then call or email the Editor.

Are manuscripts peer reviewed? Every manuscript undergoes peer review. At this time, about a third of the manuscripts do not pass peer review. Thus, no matter how local or regional, the science must be sound and the writing crisp and clear. Please note that the Journal is not a repository for manuscripts that have failed elsewhere because they often will wind up in the same or a similar reviewer's hands with the same result. It still amazes me that I receive manuscripts that obviously have been rejected elsewhere. How do I know? They are still in the format for the previous journal! Every manuscript needs to be in the style and format of the Journal (Guidelines for Contributors in this issue). Each undergoes editing for spelling, grammar, syntax, and style but not until the external reviews have been completed. Although it is not always just, external reviewers often are not as kind to manuscripts that are tough to read.

There are two articles that I have found valuable as the Journal Editor.

George, T. M. 1993. History of the Kentucky Academy of Science~1914–1992. Transactions of the Kentucky Academy of Science 54:112–135.

Hill, J. B., and C. Madarash-Hill. 2003. The Journal of the Kentucky Academy of Science: indexing and availability of a Kentucky-based resource. Journal of the Kentucky Academy of Science 64:121–127.

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