

Seasonal Phenology of the Cerambycid Beetles of East Central Illinois

LAWRENCE M. HANKS,^{1,2} PETER F. REAGEL,^{1,3} ROBERT F. MITCHELL,^{1,4} JOSEPH C. H. WONG,¹
 LINNEA R. MEIER,¹ CHRISTINA A. SILLIMAN,¹ ELIZABETH E. GRAHAM,^{1,5}
 BECCA L. STRIMAN,^{1,6} KENNETH P. ROBINSON,¹ JUDITH A. MONGOLD-DIERS,¹
 AND JOCELYN G. MILLAR⁷

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ABSTRACT We summarize field data on the species composition and seasonal phenology of the community of cerambycid beetles of east central Illinois. Data were drawn from field bioassays conducted during 2009–2012 that tested attraction of adult beetles of diverse species to a variety of synthetic pheromones and host plant volatiles. In total, 34,086 beetles of 114 species were captured, including 48 species from the subfamily Cerambycinae, 41 species from Lamiinae, 19 species from Lepturinae, 2 species from Spondylidinae, and 1 species each from Necydalinae, Parandrinae, Prioninae, and Disteniidae. Most of the best-represented species were attracted to pheromones that were included in field experiments, particularly species that use (*R*)-3-hydroxyhexan-2-one as a pheromone component. The species captured and their patterns of abundance and seasonal phenology were similar to those in an earlier study conducted in Pennsylvania. The most abundant species identified in both studies included the cerambycines *Elaphidion mucronatum* (Say), *Neoclytus acuminatus acuminatus* (F.), *Neoclytus mucronatus mucronatus* (F.), and *Xylotrechus colonus* (F.). Cerambycine species became active in an orderly progression from early spring to late fall, whereas most lamiine species were active in the summer and fall, and lepturine species were limited to the summer. Potential cross attraction between some cerambycine species that shared pheromone components may have been averted by differences in seasonal activity period and by minor pheromone components that acted as synergists for conspecifics, antagonists for heterospecifics, or both. These results provide quantitative data on the abundance and seasonal phenology of a large number of species.

KEY WORDS pheromone, semiochemical, cross attraction, reproductive isolation

Despite the economic importance of many cerambycid species within their native ranges, the threat they pose as exotic invaders worldwide, and their popularity with naturalists and insect collectors, remarkably little is known about the basic biology of even quite common and well-known species (Solomon 1995, Hanks 1999). The Cerambycidae represents one of the largest families in Insecta, with >30,000 identified species (Slipinski et al. 2011), but study of their natural history and behavior is hindered by the crepuscular and nocturnal habits of the adults of many species coupled with long life cycles (Linsley 1961). Information about host plants, geographic distribution, and

seasonal phenology of particular cerambycid species is often summarized from rearing and collection records that originate from different parts of the species range. Thus, the flight period of widely distributed North American species, as reported in secondary literature, may range from the earliest date of emergence in the southern part of the range to cessation of flight in the northern extremes (references indexed in Linsley and Chemsak 1997).

There appears to be considerable parsimony within Cerambycidae in relation to pheromone biosynthesis and use, with sympatric species sharing pheromone components or even producing pheromones of identical composition (Barbour et al. 2011; Mitchell et al. 2011, 2013; Teale et al. 2011; Wong et al. 2012; Hanks and Millar 2013). For example, (*R*)-3-hydroxyhexan-2-one is a common, and often the sole component of volatile pheromones of many species in the large subfamily Cerambycinae (Hanks et al. 2007, Hanks and Millar 2013). Recent research has revealed that cross attraction between cerambycid species with similar pheromone chemistry may be limited or averted altogether by seasonal segregation of species because of differences in flight period (Hanks and Millar 2013). However, flight periods of individual cerambycid spe-

¹ Department of Entomology, University of Illinois at Urbana-Champaign, Urbana, IL 61801.

² Corresponding author, e-mail: hanks@life.illinois.edu.

³ Current address: USDA APHIS PPQ CPHST Otis Laboratory, Buzzards Bay, MA.

⁴ Current address: Center for Insect Science, University of Arizona, Tucson, AZ 85721.

⁵ Current address: USDA Forest Service, 11175 Auke Lake Way, Juneau, AK 99801.

⁶ Current address: Dept. of Biology, University of Prince Edward Island, Charlottetown, PEI, Canada.

⁷ Department of Entomology, University of California, Riverside, CA 92521.

Table 1. Study sites for field bioassays conducted in east central Illinois during 2009–2012

County	Name	GPS coordinates	Area
Champaign	Brownfield Woods ^a	40° 8' 42.8028" N, 88° 9' 55.659" W	26ha
	CCDC Collins Woods ^a	40° 8' 17.7426" N, 88° 2' 12.5082" W	6 ha
	City of Urbana Landscape and Recycling Center	40° 7' 13.8972" N, 88° 11' 10.9248" W	3 ha
	Homer Lake Forest Preserve ^b	40° 3' 32.3886" N, 87° 58' 59.5272" W	330 ha
	Lake of the Woods Preserve ^b	40° 12' 11.3934" N, 88° 23' 27.9954" W	135 ha
	Middle Fork River Forest Preserve ^b	40° 23' 52.2306" N, 87° 59' 28.7154" W	890 ha
	Nettie Hart Memorial Woods ^a	40° 13' 46.833" N, 88° 21' 28.2594" W	16 ha
	Phillips Tract ^a	40° 7' 51.4986" N, 88° 9' 8.301" W	52 ha
	Private residence in Urbana, IL	40° 5' 49.4412" N, 88° 12' 11.3832" W	0.1 ha
	Trelease Woods ^a	40° 8' 5.5422" N, 88° 8' 34.0656" W	29 ha
	Univ. Illinois Forestry Plantation ^a	40° 4' 43.7154" N, 88° 12' 39.8658" W	16 ha
	Univ. Illinois Operations and Maintenance ^a	40° 5' 7.9332" N, 88° 12' 59.5362" W	9 ha
	Marshall	Privately owned woodlot	41° 3' 5.835" N, 89° 21' 8.8416" W
McLean	Funk Forest ^a	40° 20' 30.2028" N, 89° 8' 50.7366" W	25 ha
Piatt	Allerton Park ^a	39° 59' 7.2312" N, 88° 39' 0.5292" W	600 ha
Vermilion	Edgar and Sophia Richter Research Area ^a	40° 5' 19.9422" N, 87° 48' 42.3102" W	9 ha
	Forest Glen Preserve ^c	40° 0' 54.576" N, 87° 34' 3.756" W	3 ha
	Rutan Research Area ^a	40° 4' 22.0938" N, 87° 54' 22.8882" W	10.4 ha
	Vermilion River Observatory ^a	40° 3' 55.9908" N, 87° 33' 40.7772" W	192 ha

^a University of Illinois (<http://research.illinois.edu/cna/>).

^b Champaign County Forest Preserves District, Illinois (<http://www.ccfpd.org/>).

^c Vermilion County Conservation District (<http://www.vccd.org/>).

cies are rarely fully characterized, and there are even fewer studies that document seasonal phenology of multiple species within a local community (Löyttyniemi and Löyttyniemi 1983, Paro et al. 2012). This information is critical for understanding the role of volatile compounds that are produced by adult cerambycids, discerning which components serve as pheromones and which serve as antagonists (Baker 2008), and more generally, how sympatric and synchronic cerambycid guilds and communities limit interference in their individual pheromone channels.

In the present article, we summarize field data on the seasonal phenology of the cerambycid community of east central Illinois that has been the target of semiochemical research for the last decade (Lacey et al. 2004, 2007, 2008, 2009; Ginzel and Hanks 2005; Mitchell et al. 2011; Hanks et al. 2012; Wong et al. 2012). Flight seasons of cerambycid species in Illinois are compared with those recently reported from a study conducted in Pennsylvania that used similar methods (Hanks and Millar 2013). Data for the current study were drawn from field bioassays conducted during 2009–2012 that tested attraction of the local community of cerambycid species to a variety of synthetic pheromones, blends of pheromones, host plant volatiles, and blends of pheromones with plant volatiles. These bioassays were consistent in their methods but varied in their objectives. Because the overarching design of the trapping program was not balanced for any species in terms of consistent numbers of traps with appropriate lures over time, the data were not suitable for analysis of temporal trends in abundance. Moreover, care should be taken in extrapolating the data to compare population sizes of different species because species undoubtedly varied in the strength of their attraction to synthetic pheromones, in how attraction was influenced by release rates of pheromone emitters, in the efficacy with which they were captured by traps, and by other factors relating to the

efficiency and effectiveness of the trapping methodology. Thus, the number of beetles captured may not be closely correlated with local population density.

Despite the fact that the data summarized here originated from field bioassays that were not intended to characterize phenology of cerambycids, the large number of traps that were deployed across many and widespread study sites throughout the entire flight seasons of all the species yielded valuable information for assessing the composition of the cerambycid community and for characterizing the seasonal activity periods of individual species.

Materials and Methods

Field bioassays were conducted from early spring to late fall of 2009–2012 at 19 study sites in east central Illinois, most of which were wooded with mature second-growth or successional hardwoods and dominated by oaks, hickories, ash, and maple (Table 1). Exceptions were the University of Illinois Forestry Plantation, which included a small stand of conifers, and a private residence in an urban forest with a great diversity of both hardwoods and conifers (Table 1).

Beetles were trapped with black flight-intercept panel traps (corrugated plastic, 1.2 m high by 0.3 m wide, Alpha Scents Inc., West Linn, OR). Traps were treated with the fluoropolymer dispersion Fluon (Northern Products, Woonsocket, RI) to render surfaces more slippery and improve trapping efficiency, and were suspended from frames of PVC irrigation pipes (Graham et al. 2010). Trap basins contained ≈300 ml of propylene glycol or a saturated sodium chloride solution as preservatives. For most experiments, a single trap line was set up at each study site, including a control trap baited with a lure containing only solvent, and traps were positioned at least 10 m apart. Captured beetles were usually collected from traps every 2–3 d, but collection periods were some-

times considerably extended for traps at more distant sites or during periods of inclement weather. The date of capture for individual specimens was estimated as the median between the date on which the specimen was collected from the trap and the date on which the trap was previously serviced. We include in our calculations of activity period only specimens for which the range between those two dates was 10 d or less. Because the median date is used, the maximum error in estimating capture date was 5 d.

Traps were baited with synthetic pheromones of many native cerambycid species, as formally confirmed with earlier research (Hanks et al. 2012, Wong et al. 2012). These pheromones are produced by males and attract both sexes (see references below). The following chemicals were used in trap lures (references are relevant for cerambycid species of east central Illinois, and provide sources of chemicals):

1) (*RS*)-3-hydroxyhexan-2-one, the *R* enantiomer of which is a pheromone component of many cerambycine species in the tribes Anaglyptini, Callidiini, Elaphidiini, and especially Clytini, and at least an attractant for many other species in these and other tribes (Lacey et al. 2004, 2007, 2008, 2009; Hanks and Millar 2013);

2) *Syn*- and *anti*-2,3-hexanediols, specific enantiomers of which are pheromone components of cerambycine species in the tribes Curiini, Clytini, and Elaphidiini (Lacey et al. 2004, 2008, 2009);

3) (*E/Z*)-6,10-dimethyl-5,9-undecadien-2-ol and (*E/Z*)-6,10-dimethyl-5,9-undecadien-2-yl acetate (fuscumol and fuscumol acetate), attractants and probable pheromones of many species in the Spondylidinae and in the lamiine tribes Acanthocini and Acanthoderini (Mitchell et al. 2011);

4) 2-(undecyloxy)-ethanol (monochamol), pheromone of the lamiine *Monochamus carolinensis* (Olivier) (Allison et al. 2012) and a number of congeners (Pajares et al. 2010, Teale et al. 2011, Fierke et al. 2012);

5) 2-methylbutan-1-ol, enantiomers of which are pheromone components of the early-season cerambycine *Megacyllene caryae* (Gahan), tribe Clytini, and cerambycine species in the genus *Phymatodes*, tribe Callidiini (Hanks et al. 2007, 2012);

6) Citral, an isomeric blend of neral and geranial, important pheromone components of *M. caryae* (Lacey et al. 2008);

7) Ethanol and α -pinene, plant volatiles that may attract certain cerambycid species or enhance attraction to pheromones (Hanks et al. 2012, Hanks and Millar 2013).

Lures were usually formulated to contain 25 mg of each pheromone enantiomer (i.e., 50 mg of a racemate or 100 mg of the racemic, (*E/Z*)-fuscumol, and (*E/Z*)-fuscumol acetate), as single components or in blends dissolved in ethanol (2009, 2010) or isopropanol (2011, 2012). Pheromone emitters were transparent polyethylene sachets (press-seal bags, Bagette model 14770, 5.1 by 7.6 cm, 0.05-mm wall thickness, Cousin Corp., Largo, FL) that were hung in the center of traps and replaced as needed (generally every 2–3

wk). Plant volatiles were emitted by high release lures (95% ethanol, ≈ 0.4 g/d, model IP036–100; α -pinene, ≈ 2 g/d, model IP037–75; Synergy Semiochemicals Corp., Burnaby, British Columbia, Canada).

Each year, the timing of emergence of the earliest species was ascertained by deploying individual sentinel traps baited with pheromones or blends specific to those species at selected sites several weeks before emergence began. Trapping continued through late fall until very few, if any, beetles were captured for at least 2 wk. Subsequent experiments measured the attraction of cerambycids to individual compounds and pairwise and higher order combinations of compounds for periods of at least 1 mo (Hanks et al. 2012, Wong et al. 2012). As a result, traps baited with a diverse array of pheromones and attractants were continually present in widely scattered areas throughout the entire season that adult cerambycid beetles were active.

Field data from pheromone bioassays are inherently of questionable utility for assessing flight period because beetles may be attracted to traps only when receptive to mating. For example, many species in the subfamily Lamiinae require a period of maturation feeding before mating, which may last several weeks (Hanks 1999). The timing of their capture by pheromone traps, therefore, may provide an underestimate of flight period. However, in the current study, this potential bias is at least partly alleviated by including all trap capture data, regardless of experimental treatment, and including control treatments. Even unbaited traps capture cerambycid beetles (Schmitz 1984), and our earlier studies have revealed that control traps capture small numbers of many species in east central Illinois (Hanks et al. 2012, Wong et al. 2012, and references therein).

Flight period across all 4 yr of the study was summarized by converting field data to presence or absence criteria, i.e., using only ordinal dates on which specimens of a given species were captured, regardless of the number of traps involved and the number of beetles captured. Thus, flight phenology for each species was characterized as the distribution of ordinal dates on which any number of specimens was captured by any trap. Of course, the number of ordinal dates of capture per species was strongly autocorrelated with the number of specimens because species represented by only a few specimens could only be associated with a few dates. The relationship between numbers of specimens per species (across years) and number of ordinal dates was well described by an asymptotic exponential function (Fig. 1). The one highly conspicuous outlier was *M. caryae*, adults of which were active for only a brief period in early spring and were attracted in great numbers to traps baited with citral (L.M.H., unpublished data). The asymptotic nature of the nonlinear relationship is because of seasonality of the cerambycid species. Even the most numerous species were active for only part of the season (see Results), and therefore could only be trapped on a limited number of ordinal dates.

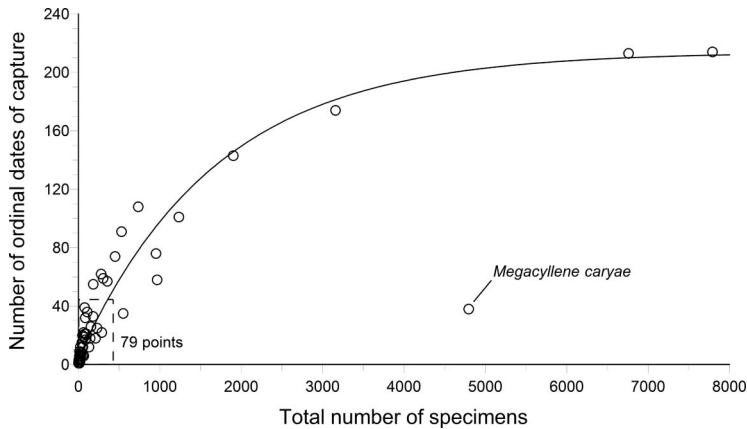


Fig. 1. Relationship between the number of specimens of cerambycid species that were captured during 2009–2012 and the number of ordinal dates on which they were captured. Best fit regression equation: $Y = 213.9 - 209.18e^{(-X/1696.87)}$ (nonlinear regression; PROC REG; $r^2 = 0.94$; $F_{1,107} = 1,639$; $P < 0.0001$). Outlier point for *Megacyllene caryae* (Gahan) not included in analysis (see Results). Number of species differs slightly from Table 2 because date of capture could not be calculated for specimens of some species that were represented by only a few specimens (see Methods).

The phenology of the flight seasons of cerambycid species was estimated by combining ordinal date data for all 4 yr and calculating the mean and standard deviation, with the onset of activity estimated by subtracting one standard deviation from the mean and the cessation of activity estimated by adding one standard deviation to the mean. The resulting range of ordinal dates (one standard deviation around the mean) therefore encompasses $\approx 68\%$ of the ordinal dates in the data set, a fairly conservative assessment of activity period. Years with the greatest number of ordinal dates for a particular species had the greatest influence on its estimated activity period.

We tested the accuracy of our assessment of seasonal phenology by examining the linear relationship between estimated onset of emergence in Illinois versus that from the Pennsylvania study (Hanks and Millar 2013) for 33 species that were represented by at least 20 specimens in both studies, regardless of capture year. A separate analysis was conducted to determine whether the linear relationship between the activity period in Illinois versus Pennsylvania would be better characterized with greater sample sizes, using only data for the seven species that were well represented in every year of both studies (i.e., at least 10 specimens in each year), including the cerambycines *Anelaphus villosus* (F.), *Cyrtophorus verrucosus* (Olivier), *Elaphidion mucronatum* (Say), *Neoclytus acuminatus acuminatus* (F.), *Neoclytus mucronatus mucronatus* (F.), and *Xylotrechus colonus* (F.), and the lamiine *Graphisurus fasciatus* (Degeer). We also compared the duration of activity periods of the same seven species in Illinois versus Pennsylvania to confirm that our estimates were consistent.

Data were analyzed with SAS/STAT software (version 9.2 for Windows; SAS Institute Inc., Cary, NC). Differences between means were tested by analysis of variance (ANOVA) (PROC GLM), with differences between pairs of means tested with the REGWQ

means-separation test, which controls for maximum experiment-wise error rates. Linear relationships were tested using linear regression (PROC REG; hypotheses about slope and intercept tested with the TEST option). Distributions of ordinal dates of capture were examined for evidence of multimodality (indicative of multivoltinism) and tested for departures from normality by using the Shapiro–Wilk test (Zar 2010). This test for normality was limited to species represented by at least 20 dates across years because it is overly conservative at small sample sizes, failing to reject the null hypothesis of normality (SAS Institute 2008).

Taxonomy follows Monné and Bezark (2013). Representative specimens of all species have been retained in the laboratory of L.M.H., and voucher specimens have been deposited with the collection of the Illinois Natural History Survey, Champaign, IL.

Results

In total, 34,086 cerambycid beetles of 114 species were captured by panel traps in east-central Illinois during the 4-yr period (Table 2), including 48 species from 16 tribes of the subfamily Cerambycinae, 41 species from 8 tribes of Lamiinae, 19 species from 2 tribes of Lepturinae, 2 species from Spondylidinae, and 1 species each from Necydalinae, Parandrinae, Prioninae, and Disteniidae. The only exotic species was *Phymatodes testaceus* (L.), native to Europe (Swift and Ray 2010). Pheromones and other semiochemicals have been identified previously for many of the species that were trapped (Hanks and Millar 2013).

Several species were captured in small numbers (Fig. 2), with 24 species ($\approx 21\%$) represented by single specimens during 4 yr of trapping (Table 2). However, only 14 species ($\approx 12\%$ of the total) accounted for $\approx 90\%$ of the specimens that were captured, including (in order of abundance, from Table 2) the ceramby-

Table 2. Species of cerambycid beetles and numbers captured by panel traps during 2009–2012 in east central Illinois

Taxonomy	2009	2010	2011	2012	Total
Cerambycinae					
Anaglyptini					
<i>Cyrtophorus verrucosus</i> (Olivier)	14	232	479	228	953
Bothriospilini					
<i>Knulliana cincta</i> (Drury)		2	1	1	4
Callidiini					
<i>Phymatodes aereus</i> (Newman)	9	5	131	65	210
<i>Phymatodes amoenus</i> (Say)		63	169	55	287
<i>Phymatodes lengi</i> Joutel			120	430	550
<i>Phymatodes testaceus</i> (L.)		4	13	46	63
<i>Phymatodes varius</i> (F.)			1	9	10
<i>Physocnemum brevilineum</i> (Say)		5	1	5	11
Clytini					
<i>Clytoleptus albofasciatus</i> (Laporte & Gory)			1	7	8
<i>Clytus ruricola</i> (Olivier)			9	2	19
<i>Megacyllene caryae</i> (Gahan)	338	2,401	1,466	590	4,795
<i>Megacyllene robiniae</i> (Forster)		1			1
<i>Neoclytus a. acuminatus</i> (F.)	87	928	2,145	3,600	6,760
<i>Neoclytus caprea</i> (Say)	27	32	86	83	228
<i>Neoclytus horridus</i> (LeConte)				1	1
<i>Neoclytus j. jouteli</i> Davis	1		2	11	14
<i>Neoclytus l. leucozonus</i> Laporte and Gory	2		1		3
<i>Neoclytus m. mucronatus</i> (F.)	640	1,003	785	731	3,159
<i>Neoclytus scutellaris</i> (Olivier)		6	23	100	129
<i>Sarosthes fulminans</i> (F.)	4	62	10	20	96
<i>Xylotrechus colonus</i> (F.)	597	1,093	1,866	4,235	7,791
<i>Xylotrechus convergens</i> LeConte			3	9	12
<i>Xylotrechus s. sagittatus</i> (Germar)				1	1
Curiini					
<i>Curius dentatus</i> Newman	1	13	9	43	66
Dryobiini					
<i>Dryobius sexnotatus</i> LeConte				2	2
Eburini					
<i>Eburia quadrigeminata</i> (L.)	10	7	15	23	55
Elaphidiini					
<i>Anelaphus parallelus</i> (Newman)	2			5	7
<i>Anelaphus pumilus</i> (Newman)	21	51	524	371	967
<i>Anelaphus villosus</i> (F.)	11	25	26	14	76
<i>Elaphidion mucronatum</i> (Say)	17	68	142	302	529
<i>Enaphalodes atomarius</i> (Casey)				2	2
<i>Enaphalodes rufulus</i> (Haldeman)	1				1
<i>Micranoplum unicolor</i> (Haldeman)				3	3
<i>Parelapheidion aspersum</i> (Newman)	14	21	25	48	108
<i>Parelapheidion incertum</i> (Newman)	7	15	20	17	59
<i>Psyrassa unicolor</i> (Randall)				1	1
<i>Stenosphenus notatus</i> (Olivier)		4	1	1	6
Hesperophanini					
<i>Tylonotus bimaculatus</i> Haldeman			2	3	5
Ibidionini					
<i>Heterachthes quadrimaculatus pallidus</i> Haldeman	1	1	1	12	15
Molorchini					
<i>Molorchus b. bimaculatus</i> Say			2		2
Obrini					
<i>Obrium maculatum</i> (Olivier)		4	2	10	16
<i>Obrium rufulum</i> Gahan			1		1
Rhopalophorini					
<i>Rhopalophora longipes</i> (Say)			2		2
Smodicini					
<i>Smodicum cucujiforme</i> (Say)			28	1	29
Tillomorphini					
<i>Euderces picipes</i> (F.)	10	10	22	31	73
<i>Euderces pini</i> (Olivier)		34	25	2	61
Trachyderini					
<i>Purpuricenus axillaris</i> Haldeman			1		1
<i>Purpuricenus paraxillaris</i> MacRae				1	1
Lamiinae					
Acanthocinini					
<i>Astyleiopus variegatus</i> (Haldeman)	6	83	223	423	735
<i>Astylidius parvus</i> Casey	4	28	264	154	450

Continued on following page

Table 2. Continued

Taxonomy	2009	2010	2011	2012	Total
<i>Astylopsis collaris</i> (Haldeman)		2	2	1	5
<i>Astylopsis macula</i> (Say)	8	28	59	87	182
<i>Astylopsis sexguttata</i> (Say)		1	1	1	3
<i>Graphisurus despectus</i> LeConte	11	3	46	93	153
<i>Graphisurus fasciatus</i> (Degeer)	22	277	560	1,044	1,903
<i>Graphisurus triangulifer</i> (Haldeman)				1	1
<i>Hyperplatys aspersa</i> (Say)			1		1
<i>Hyperplatys maculata</i> Haldeman	2	2	8	4	16
<i>Leptostylus transversus</i> (Gyllenhal in Schoenherr)	1		1	74	76
<i>Lepturges angulatus</i> (LeConte)	4	241	366	623	1,234
<i>Lepturges confluens</i> (Haldeman)	3	18	91	67	179
<i>Lepturges pictus</i> (LeConte)		2	1	2	5
<i>Lepturges regularis</i> (LeConte)		1	36	48	85
<i>Lepturges symmetricus</i> (Haldeman)		4	6	5	15
<i>Sternidius alpha</i> (Say)		25	75	203	303
<i>Sternidius mimeticus</i> (Casey)		1			1
<i>Sternidius misellus</i> (LeConte)				7	7
Acanthoderini					
<i>Aegomorphus modestus</i> (Gyllenhal in Schoenherr)	3	80	66	129	278
<i>Oplasia nubila</i> (LeConte)		6	12	6	24
<i>Urgleptes querci</i> (Fitch)		7	16	23	46
<i>Urgleptes signatus</i> (LeConte)		4	4	4	12
Desmiphorini					
<i>Eupogonius pauper</i> LeConte	1	3		7	11
<i>Eupogonius tomentosus</i> (Haldeman)			1		1
<i>Psenocerus supernotatus</i> LeConte		10	15	11	36
Dorcaschematini					
<i>Dorcaschema alternatum</i> (Say)				4	4
<i>Dorcaschema cinereum</i> (Olivier)	3	3	5	10	21
<i>Dorcaschema nigrum</i> (Say)			2		2
Monochamini					
<i>Goes pulcher</i> (Haldeman)				1	1
<i>Microgoes oculatus</i> (LeConte)		5	38	6	49
<i>Monochamus carolinensis</i> (Olivier)		46	123	186	355
Obereïini					
<i>Obera perspicillata</i> Haldeman				1	1
Pogonocherini					
<i>Ecyrus d. dasycerus</i> (Say)	3	7	6	17	33
<i>Pogonocherus mixtus</i> Haldeman		1			1
Saperdini					
<i>Saperda discoidea</i> F.	1	2	4	17	24
<i>Saperda imitans</i> Felt & Joutel		4	16	59	79
<i>Saperda lateralis</i> F.	4	1	7	2	14
<i>Saperda puncticollis</i> Say				1	1
<i>Saperda tridentata</i> Olivier	3	1	13	5	22
<i>Saperda vestita</i> Say	1	1	2	2	6
Lepturinae					
Lepturini					
<i>Analeptura lineola</i> (Say)			1		1
<i>Bellamira scalaris</i> (Say)		2	2	9	13
<i>Brachyleptura rubrica</i> (Say)	1		3	8	12
<i>Centrodera sublineata</i> LeConte			3		3
<i>Gaurotes cyanipennis</i> (Say)		7	15	32	54
<i>Grammoptera haematites ruficeps</i> LeConte			1		1
<i>Stenelytrana emarginata</i> (F.)		3			3
<i>Stenocorus cinnamopterus</i> (Randall)			2	2	4
<i>Stenocorus schaumii</i> (LeConte)			1		1
<i>Strangalepta abbreviata</i> Casey	1				1
<i>Strangalia bicolor</i> (Swederus)	4		4		8
<i>Strangalia famelica solitaria</i> Newman	1			2	3
<i>Strangalia luteicornis</i> (F.)	15	3		1	19
<i>Strophiona nitens</i> (Forster)	3		8	1	12
<i>Trigonarthris proxima</i> (Say)			1		1
<i>Typocerus deceptus</i> Knoll	8		1	3	12
<i>Typocerus lugubris</i> (Say)	6	1	30	4	41
<i>Typocerus sinuatus</i> (Newman)			1		1
<i>Typocerus v. velutinus</i> (Olivier)	7	2	3	3	15
Necydalinae					
<i>Necydalis mellita</i> (Say)	1	1	1	7	10

Continued on following page

Table 2. Continued

Taxonomy	2009	2010	2011	2012	Total
Parandrinae					
Parandrini					
<i>Neandra brunnea</i> (F.)	6	28	38	72	144
Prioninae					
Prionini					
<i>Orthosoma brunneum</i> (Forster)	4	3	33	33	73
Spondylidinae					
Asemini					
<i>Arhopalus rusticus</i> (Haldeman)			1		1
<i>Asemum striatum</i> (L.)				1	1
Disteniidae					
Disteniini					
<i>Elytrimitatrix undata</i> (F.)	28	8	24	24	84
Total no. of specimens:	1,979	7,051	10,405	14,651	34,086

cines *X. colonus*, *N. a. acuminatus*, *M. caryae*, *N. m. mucronatus*, *Anelaphus pumilus* (Newman), *C. verrucosus*, *Phymatodes lengi* Joutel, and *E. mucronatum*, and the lamiines *G. fasciatus*, *Lepturges angulatus* (LeConte), *Astyleiopus variegatus* (Haldeman), *Astyliidius parvus* Casey, *M. carolinensis*, and *Sternidius alpha* (Say). The most numerous cerambycine species (with hundreds of specimens) were those attracted to pheromones that were deployed frequently in various field experiments. For example, *N. a. acuminatus* was caught on the greatest number of collection dates ($N = 297$) and was attracted to traps baited with racemic *syn*-2,3-hexanediol as a single component or as a component of a blend. The pheromone of this species has been identified as (2*S*,3*S*)-2,3-hexanediol, one of the two enantiomers comprising the racemic *syn*-2,3-hexanediol (Lacey et al. 2004). Also, particularly numerous were cerambycine species that produce (*R*)-3-hydroxyhexan-2-one as their sole or primary pheromone component (Table 2), including *A. pumilus*, *C. verrucosus*, *Neoclytus caprea* (Say), *N. m. mucronatus*, *Neoclytus scutellaris* (Olivier), *Phymatodes aereus* (Newman), *Phymatodes amoenus* (Say), *P. lengi*, and *X. colonus* (Lacey et al. 2007, 2009; Mitchell et al. 2013; L.M.H., unpublished data). The cerambycine *M. caryae* was strongly attracted to citral

(Lacey et al. 2008), and the most numerous lamiine species were those known to be attracted to fuscumol, fuscumol acetate, or both (Mitchell et al. 2011), including *A. variegatus* (males produce [*S*]-fuscumol and [*S*]-fuscumol acetate; Hughes et al. 2013), *A. parvus*, *G. fasciatus*, *L. angulatus*, and *S. alpha*. The lamiine *M. carolinensis* was attracted to its recently identified pheromone, monochamol (Allison et al. 2012).

Some species whose pheromones were among those commonly used in trap lures nevertheless were rarely caught, such as *Xylotrechus convergens* LeConte (produces only [*R*]-3-hydroxyhexan-2-one) and *Enaphalodes atomarius* (Casey) (produces [2*S*,3*S*]-2,3-hexanediol; L.M.H., unpublished data). Other species whose pheromones are known were captured regularly but always in relatively small numbers, such as *P. testaceus* (produces only [*R*]-2-methylbutan-1-ol) and *Eudercus pini* (Olivier) (produces only [*R*]-3-hydroxyhexan-2-one; L.M.H., unpublished data). Therefore, the number of beetles captured was not solely determined by the presence of their pheromone components in trap lures.

During field studies in Illinois, flight seasons of cerambycids began in mid-March, with the numbers of individuals captured and numbers of species increasing to a peak in mid-July and declining through the

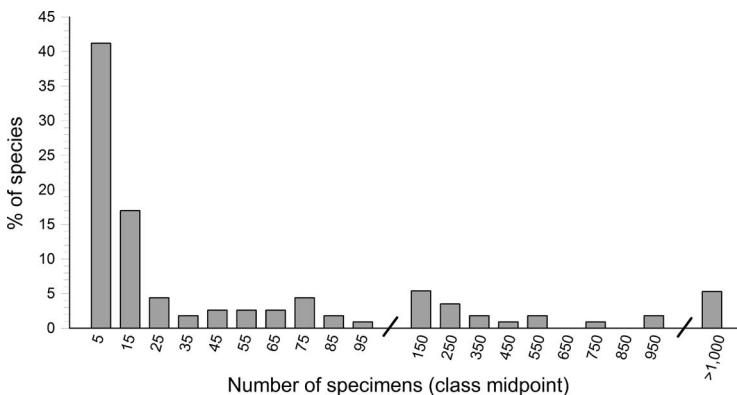


Fig. 2. Frequency distribution of numbers of specimens per cerambycid species captured during 2009–2012 in classes of 10 specimens (0–100), 100 specimens (100–1,000), and >1,000 specimens.

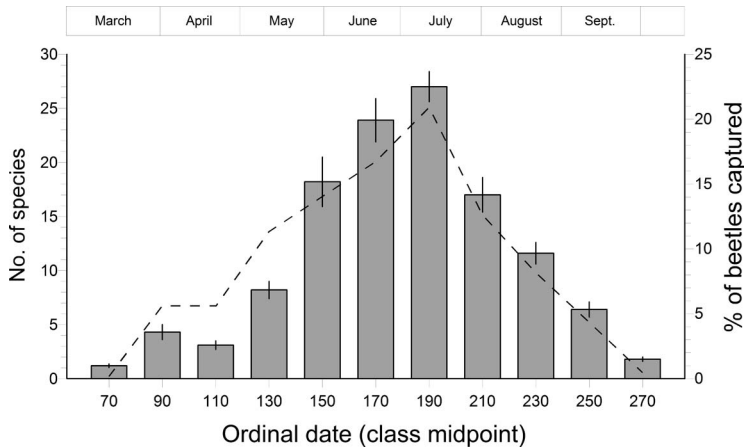


Fig. 3. Seasonal activity period of adult cerambycid beetles of all species captured during 2009–2012. Bars (left axis): Numbers of species per date class; Dotted line (right axis): Percentage of beetle specimens (of the grand total) per date class.

end of August (Fig. 3). The earliest cerambycine species were *N. caprea* and *Stenosphenus notatus* (Olivier), which typically first appeared in late March and there follows an orderly progression of cerambycine species emerging through late July, some species being active through August, and ending with the lone specimen of the locust borer, *Megacyllene robiniae* (Forster), trapped in mid-September (Table 3). The earliest collected lamiiine species was *Leptostylus transversus* (Gyllenhal in Schoenherr) in early May, but most species in that subfamily emerged in near synchrony in early June and were active during the summer and early fall. Flight seasons of lepturine species, however, were limited to May through July (Table 3), consistent with their floral feeding habits (Linsley 1961).

The onset of emergence of particular cerambycid species varied significantly every year, undoubtedly because of annual climatic variation. For example, considering the seven species that were represented by at least 20 specimens in each year, the onset of adult emergence was significantly later in 2009 than the other years (mean \pm SE: 161 ± 13), earliest in 2012 (123 ± 16), and intermediate in 2010 and 2011 (140 ± 15 and 143 ± 11 , respectively; Fig. 4; means significantly different, overall ANOVA $F_{9,27} = 50.7$, $P < 0.0001$, year effect $F_{3,27} = 21.5$, $P < 0.0001$; species effect $F_{6,27} = 65.2$, $P < 0.0001$).

Despite annual variation in activity periods, the distribution of ordinal dates on which beetles were captured across all 4 yr of the study were clearly unimodal, with single peaks of trap capture. The cerambycine *N. a. acuminatus* had the longest flight season of the cerambycines and showed a broad distribution of ordinal dates (Fig. 5A). The non-normal distribution of the data in this case was due at least in part to the fact that the Shapiro–Wilk test is overly sensitive to departures from normality at very high sample sizes (SAS Institute 2008). It might be expected that this broad distribution of dates across years was because of differences between years in the timing of peak activity. However, an examination of

the data by year (Fig. 5B) revealed similar broad flight seasons in each year, suggesting that combining data across years yielded an accurate assessment of seasonal activity.

Considering the other cerambycine species that were relatively numerous (i.e., captured on at least 20 dates), distributions of capture dates approximated the normal distribution for *N. caprea*, *C. verrucosus*, and *E. mucronatum* (Fig. 6). However, distributions again were significantly non-normal for *X. colonus* and *N. mucronatus*, the species with the longest flight periods and greatest sample sizes (Fig. 6). Frequency distributions of ordinal dates were similarly unimodal for most species in Lamiinae, with the most numerous species, *G. fasciatus*, again having a non-normal distribution (Fig. 7). Species with very long flight seasons but low sample sizes showed no evidence of multiple generations, such as *Leptostylus transversus* and *Lep- turges regularis* (LeConte) (Table 3), which were captured in small numbers throughout their long flight periods in every year.

Flight seasons of cerambycid species in Illinois progressed in very similar order to that found in the study conducted in Pennsylvania (Table 2; Hanks and Millar 2013). For the 33 species that were well represented in both studies (see Methods), the averaged onset of emergence in Illinois was closely correlated with that in Pennsylvania (Fig. 8A; $r^2 = 0.91$, $F_{1,32} = 306.4$, $P < 0.0001$), with the slope not significantly different from unity ($F_{1,31} = 2.84$, $P = 0.10$). Differences between the two studies in climatic conditions and possibly other environmental factors are probably responsible for the intercept not passing through the origin (i.e., significantly different from 0; $F_{1,31} = 9.21$, $P = 0.0048$). The separate analysis using the seven species that were consistently captured in each year of both studies (see Methods) yielded a regression line with a slope that was nearly identical to that of the 33 species (Fig. 8A, dotted line; $r^2 = 0.85$, $F_{1,6} = 34.0$, $P = 0.0021$; slope not significantly different from that of previous analysis, $P = 0.54$), suggesting that data for the 33

Table 3. Continued

Taxonomy	N	Month and beginning ordinal date of 10-date class																			
		Mar.		April			May			June			July			Aug.			Sept.		
		70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260
<i>Astyleiopus variegatus</i>	140									-	-	-	-	-	-	-					
<i>Graphisurus fasciatus</i>	208									-	-	-	-	-	-	-					
<i>Lepturges symmetricus</i>	15									-	-	-	-	-	-	-					
<i>Sternidius mimeticus</i>	1											172									
<i>Pogonocherus mixtus</i>	1											175									
<i>Dorcaschema nigrum</i>	2											-									
<i>Astylopsis sexguttata</i>	2											-	-	-	-	-					
<i>Lepturges angulatus</i>	148											-	-	-	-	-					
<i>Eupogonius tomentosus</i>	1												182								
<i>Astylopsis collaris</i>	5												-	-	-						
<i>Astylidius parvus</i>	91												-	-	-	-					
<i>Saperda vestita</i>	5												-	-	-	-					
<i>Hyperplatys maculata</i>	11												-	-	-	-				-	
<i>Sternidius misellus</i>	4												-	-	-	-					
<i>Graphisurus triangulifer</i>	1															220					
Lepturinae																					
<i>Centrodera sublineata</i>	3					-	-	-													
<i>Stenocorus cinnamopteris</i>	4					-	-	-													
<i>Analeptura lineola</i>	1							141													
<i>Bellamira scalaris</i>	10							-	-	-											
<i>Brachyleptura rubrica</i>	7							-	-	-											
<i>Gaurotes cyanipennis</i>	27							-	-	-	-	-									
<i>Trigonarthris proxima</i>	1									154											
<i>Grammoptera h. ruficeps</i>	1									159											
<i>Strophiona nitens</i>	10									-	-	-	-								
<i>Stenocorus schaumii</i>	1										160										
<i>Strangalia famelica</i>	3										-	-	-								
<i>Typocerus lugubris</i>	18										-	-	-								
<i>Strangalia bicolor</i>	4										-	-	-	-							
<i>Typocerus deceptus</i>	5										-	-	-								
<i>Stenelytrana emarginata</i>	3										-	-	-								
<i>Typocerus v. velutinus</i>	8										-	-	-								
<i>Strangalia luteicornis</i>	6										-	-	-	-							
<i>Typocerus sinuatus</i>	1											178									
<i>Strangalepta abbreviata</i>	1												180								
Necydalinae																					
<i>Necydalis mellita</i>	7							-	-	-											
Parandrinae																					
<i>Neandra brunnea</i>	51													-	-	-					
Prioninae																					
<i>Orthosoma brunneum</i>	35													-	-	-					
Spondylidinae																					
<i>Arhopalus rusticus</i>	1											175									
<i>Asemum striatum</i>	1														209						
Distiniidae																					
<i>Elytrimitatrix undata</i>	49													-	-	-	-				

Species (from Table 2) arranged by subfamily, initial date class, then by range of date classes. -, indicate estimated range of activity period (mean ± 1 SD ordinal date of capture, averaged across years). Sample size (N) indicates the number of dates across years used in estimating the flight activity period, larger numbers resulting in more accurate estimates. Numbers in cells are ordinal dates of capture for species represented by a single specimen. Species listed in Table 2, but missing here, were those for which date of capture could not be calculated (see Methods).

species had indeed yielded an accurate assessment of the linear relationship.

Species within the same subfamily varied considerably in activity periods (Table 3), which was partly an artifact of sample size because activity periods would be less well estimated for species represented by only a few specimens. Considering only species represented by at least 10 specimens in Illinois, the subfamilies differed significantly in activity periods, with lamiines and cerambycines having significantly longer activity periods than lepturines (means ± 1 SE: 46.6 ± 2.8, 39.1 ± 2.8, and 28.6 ± 3.4, respectively; ANOVA $F_{2,62} = 5.2, P = 0.0085$; REGWQ means separation test $P < 0.05$). The durations of activity periods in Illinois versus Pennsylvania were strongly correlated for the same seven species that were consistently captured

each year (Fig. 8B; $r^2 = 0.75, F_{1,6} = 18.8, P = 0.0075$), suggesting that the estimates of activity period for well-represented species were reasonably consistent.

Discussion

The list of cerambycid species captured in Illinois was quite similar to that from the study conducted in Pennsylvania that tested many of the same semiochemicals and blends and used similar methods (Hanks and Millar 2013). That study had a balanced experimental design, with the same treatments tested throughout the flight seasons of cerambycids in 25 counties (during 2009) or 10 counties (during 2010 and 2011), which lent itself better to assessing seasonal patterns of abundance than the current study. A

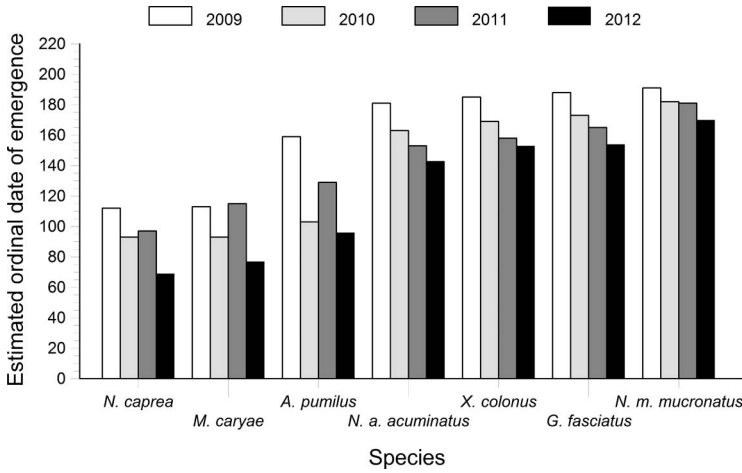


Fig. 4. Timing of the onset of flight period for the best represented cerambycid species (at least 20 specimens in each year) during 2009–2012, including cerambycines *Neoclytus caprea* (Say), *Megacyllene caryae* (Gahan), *Anelaphus pumilus* (Newman), *Neoclytus a. acuminatus* (F.), *Xylotrechus colonus* (F.), and *Neoclytus m. mucronatus* (F.), and the lamini *Graphisurus fasciatus* (Degeer). Species ordered by increasing ordinal date in 2009.

greater number of species were captured in Pennsylvania ($N = 137$) than in Illinois, as might be expected, because study sites were broadly distributed across

the state and at elevations ranging from near sea level to ≈ 600 -m elevation (Hanks and Millar 2013), whereas study sites in Illinois were limited to a few

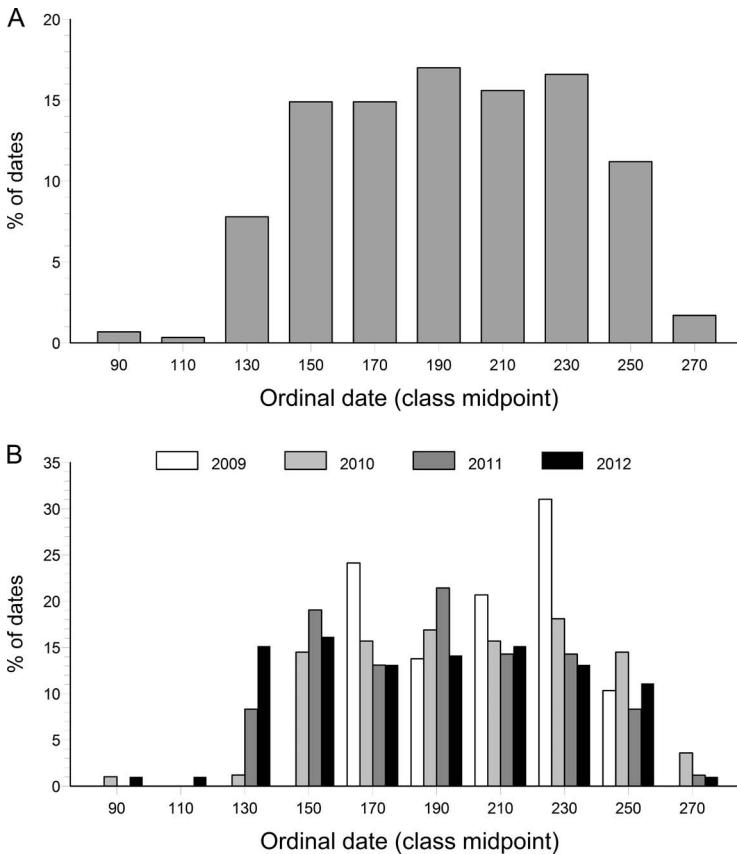


Fig. 5. Frequency distribution of ordinal dates on which adult beetles of *Neoclytus a. acuminatus* (F.) were captured: (A) Data for 2009–2012 combined ($N = 297$, Shapiro–Wilk $P = 0.0006$); (B) Data for each year presented separately (2009–2012: $N = 29$, $P = 0.15$; $N = 84$, $P = 0.08$; $N = 84$, $P = 0.09$; $N = 100$, $P = 0.011$, respectively).

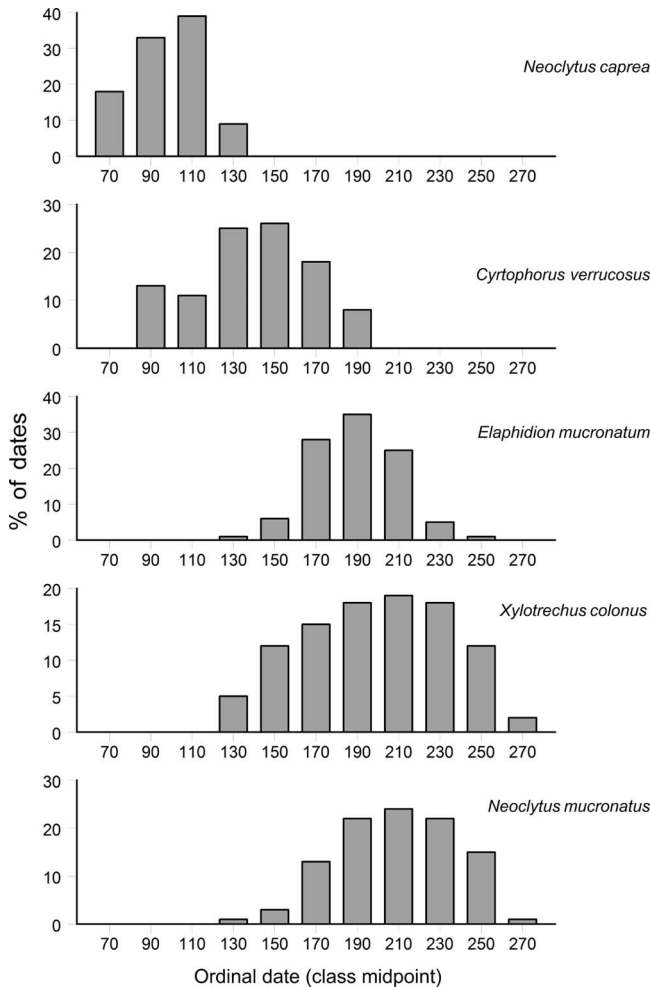


Fig. 6. Frequency distribution of ordinal dates on which adult beetles of five cerambycine species were captured during 2009–2012: *Neoclytus caprea* (Say) ($N = 33$, Shapiro–Wilk $P = 0.44$), *Cyrtophorus verrucosus* (Olivier) ($N = 96$, $P = 0.56$), *Elaphidion mucronatum* (Say) ($N = 119$, $P = 0.80$), *Xylotrechus colonus* (F.) ($N = 293$, $P = 0.0002$), and *Neoclytus m. mucronatus* (F.) ($N = 241$, $P = 0.0044$).

adjoining counties with much less variation in topography (200–350-m elevation) and plant community composition. Nevertheless, of the 114 species captured in Illinois, 98 (86%) also were captured in Pennsylvania, consistent with the reported eastern North American distributions of most of the species (Monné and Bezark 2013). Moreover, 9 of the 15 most numerous species in Pennsylvania also were among the top 15 in Illinois. Species that were abundant in Pennsylvania, but rare or absent in Illinois, were conifer specialists, including the spondylidine *Asemum striatum* (L.), the lepturine *Rhagium inquisitor inquisitor* F., and the lamiine *Monochamus scutellatus* (Say). This disparity undoubtedly was, at least partly, because of the relative scarcity of conifers at the Illinois study sites.

Our sampling of the cerambycid community of east central Illinois admittedly was biased by using traps that were baited with a limited set of pheromones.

Many of the species captured in small numbers probably were trapped passively, rather than being attracted by trap lures. This is particularly true for the lepturine species, the parandrine *Neandra brunnea* (F.), and the prionine *Orthosoma brunneum* (Forster), for which pheromones have yet to be identified. Other species, especially conifer specialists, may not have been present because most of our study sites were in stands of hardwoods. The locust borer, *M. robiniae*, represented by a single specimen, was very common in the region (Ray et al. 2009) but was not attracted by any of the pheromones that were tested, and apparently is unlikely to be intercepted by panel traps in forested habitats. The pheromone for this species is not yet known. Similarly, we did not trap adults of the very common red milkweed beetle, *Tetraopes tetrophthalmus* (Forster), in part because of the lack of an appropriate pheromone and because it is so closely associated with its milkweed hosts in

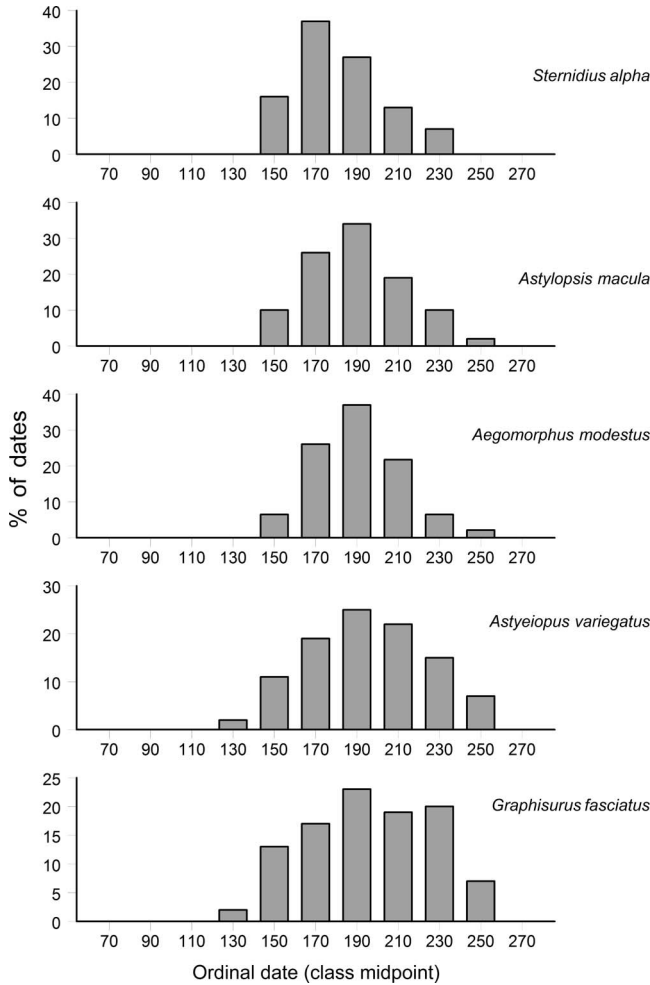


Fig. 7. Frequency distribution of ordinal dates on which adult beetles of five lamiine species were captured during 2009–2012: *Sternidius alpha* (Say) ($N = 71$, Shapiro–Wilk $P = 0.024$), *Astylopsis macula* (Say) ($N = 72$, $P = 0.72$), *Aegomorphus modestus* (Gyllenhal in Schoenherr) ($N = 92$, $P = 0.39$), *Astyleiopus variegatus* (Haldeman) ($N = 140$, $P = 0.064$), *Graphisurus fasciatus* (Degeer) ($N = 208$, $P = 0.003$).

prairie habitats (Reigel et al. 2002) rather than the forested sites where we were working. Given that most of the cerambycid species that were in the Illinois and Pennsylvania data sets are in fact ubiquitous throughout the eastern United States (Lingafelter 2007), it seems likely that species that were represented by very small numbers in either study probably were present in the area of the other study as well. Such species may indeed be rare in nature, underrepresented in our studies, or both, because of the limitations of our trapping methods.

Plant community composition does not appear to account for the much greater abundance in Illinois of some species compared with the Pennsylvania study, notably the cerambycines *A. pumilus* and *P. lengi*. Study sites in both states were well within the reported range of these species, and at least *A. pumilus* is a hardwood generalist and therefore should not be limited in distribution by host plant availability (larval

hosts of *P. lengi* are not known; Lingafelter 2007). Differences between the two studies in the relative abundance of certain species may reflect actual geographic variation in population density, but also could be because of geographic variation in pheromone chemistry or simply a consequence of differences in trapping methods. For example, funnel traps suspended from tree branches were used in the Pennsylvania study (Hanks and Millar 2013), whereas in Illinois, panel traps were positioned closer to the ground. Trap height has been shown to be a major factor in trapping cerambycids, at least some of which are associated with specific strata in the tree canopy (Graham et al. 2012).

As mentioned previously, the number of beetles of any particular species that were captured by panel traps may not be closely correlated with local population density, and thus similarities between the Illinois and Pennsylvania studies in their lists of dominant

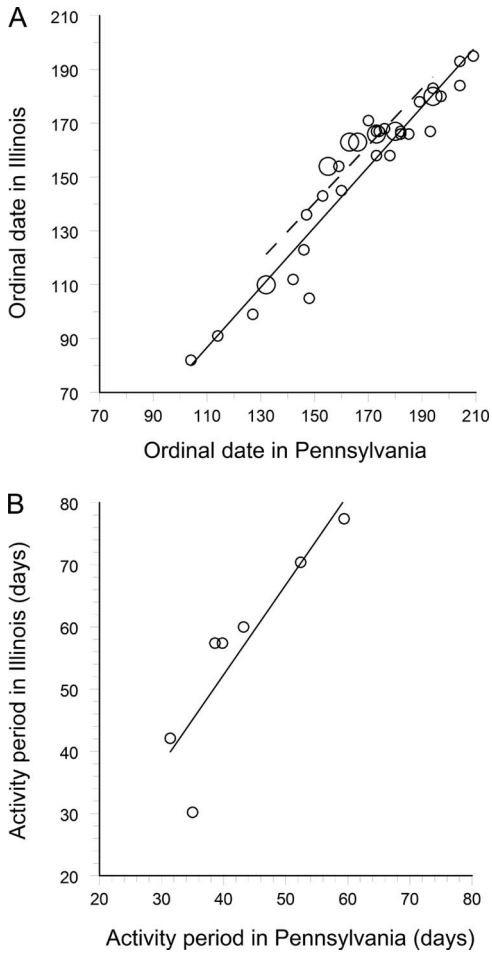


Fig. 8. Phenology of cerambycid beetles in Pennsylvania (data from Hanks and Millar 2013) compared with their phenology in Illinois (current study): (A) Estimated onset of adult emergence for 33 species (solid line indicates best fit regression model: $Y = 1.1X - 32.6$). Larger circles are for seven species with the largest sample sizes across both studies (see Results; dotted line indicates best fit regression model: $Y = 1.1X - 19.0$), including cerambycines *Anelaphus villosus* (F.), *Cyrtophorus verrucosus* (Olivier), *Elaphidion mucronatum* (Say), *Neoclytus a. acuminatus* (F.), *Neoclytus m. mucronatus* (F.), and *Xylotrechus colonus* (F.), and the lamiine *Graphisurus fasciatus* (Degeer); (B) Estimated duration of activity period for the same seven species in Pennsylvania versus Illinois (line indicates best fit regression model: $Y = 1.4X - 5.4$).

species might merely be because of the fact that traps were baited with the same attractive semiochemicals. However, two earlier field studies provide independent evidence of the relative abundance of cerambycid species in nature. In Alabama, Waters (1981) trapped cerambycid beetles over a 2-yr period by felling hardwood trees of several species and attaching sticky cards to them. In Louisiana, Newell (2008) attracted saproxylic beetles by wounding and felling deciduous trees of several species and captured beetles with unbaited flight-intercept traps in the sur-

rounding tree canopy. In these two studies, the unique methods of trapping, the differing species of trees, and differing conditions of the host materials might be expected to result in significant differences in the relative abundances of cerambycid species. Nevertheless, of the 15 most abundant species in Alabama, 7 were also in the top 15 of the Louisiana study, including (in order of dominance) the cerambycines *N. a. acuminatus*, *X. colonus*, *E. mucronatum*, *Neoclytus scutellaris* (Olivier), *N. m. mucronatus*, the lamiine *Ecyrus dasycerus dasycerus* (Say), and the disteniid *Elytrimitatrix undata* (F.). Four of these species (*N. a. acuminatus*, *X. colonus*, *E. mucronatum*, and *N. m. mucronatus*) were also in the top 15 trapped in both the Illinois and Pennsylvania studies. Given that the four studies used very different methods and also differed greatly in plant composition of the local forests, it seems likely that these cerambycid species truly are naturally abundant in the eastern United States, consistent with their being labeled as "common" or "abundant" in secondary literature (Yanega 1996, Lingafelter 2007). They are oligophagous (*N. m. mucronatus*) to highly polyphagous (the remaining three species) on eastern hardwood species (Lingafelter 2007), and larval hosts typically are stressed to moribund (*N. a. acuminatus*, *X. colonus*) or dead woody plants (*E. mucronatum*, *N. m. mucronatus*; USDA-FS 1985). Thus, all four species are likely to find hosts in most forested areas of the eastern United States.

The fact that the seasonal timing of the emergence period was quite consistent for cerambycid species in Illinois and Pennsylvania suggests that species were influenced by local climate in the same way, with yearly climatic conditions affecting development and emergence similarly for all species. Because larvae of cerambycids are endophytic, it is likely that the proximate cue for emergence of adults is thermoperiod (Danks 1987, Leather et al. 1993), which would account for the consistent order of emergence of species in different regions of their ranges.

Many cerambycine species that shared pheromone components were active at the same time of year and therefore would seem to be vulnerable to cross attraction. For example, (*R*)-3-hydroxyhexan-2-one is the sole or primary pheromone component for many species that overlapped broadly in flight period, including the dominant species *E. mucronatum*, *N. m. mucronatus*, and *X. colonus* but also (in the same order as in Table 3) *N. caprea*, *E. pini*, *C. verrucosus*, *A. pumilus*, *P. aereus*, *P. amoenus*, *P. lengi*, *Sarosesthes fulminans* (F.), *X. convergens*, *N. scutellaris*, and *Parelaphidion aspersum* (Haldeman) (Lacey et al. 2007, 2009; Mitchell et al. 2013; L.M.H., unpublished data). We have noted previously that some cerambycid species that share pheromone components avoid cross attraction by being segregated in the seasonal activity period (Hanks and Millar 2013). For example, *N. caprea* flies so early in spring that it is temporally isolated from most of the other species for which (*R*)-3-hydroxyhexan-2-one is the dominant pheromone component. For other species, minor phero-

more components may impart species specificity to a shared dominant pheromone component, such as the alkanone minor pheromone components of *C. verrucosus* and *P. aspersum* (Mitchell et al. 2013), (*R*)-2-methylbutan-1-ol of *P. amoenus* and *P. lengi* (L.M.H., unpublished data), and (2*S*,3*R*)-2,3-hexanediol of *S. fulminans* (Lacey et al. 2009, Hanks and Millar 2013). In still other cases, minor components of one species may act as antagonists of other species that share the dominant component, again minimizing cross attraction (Hanks and Millar 2013).

To date, pheromones have been formally identified from only a few lamiine species, including *A. variegatus* (Hughes et al. 2013), the South American species *Hedypathes betulinus* (Klug) (Fonseca et al. 2010), and a number of *Monochamus* species (Pajares et al. 2010, Teale et al. 2011, Allison et al. 2012, Fierke et al. 2012). However, several other lamiines have been shown to be attracted to fuscumol and fuscumol acetate (Mitchell et al. 2011, Hanks and Millar 2013), and many of these overlap in seasonal activity periods, with adults of most species being crepuscular or nocturnal (Linsley 1961). Species specificity of pheromones may be imparted by varying the ratio of fuscumol to fuscumol acetate or by the presence or absence of geranylacetone (Fonseca et al. 2010) or other compounds that are minor components in blends. Alternatively, differences between species in the chirality of fuscumol fuscumol acetate, or both may impart specificity. For example, male *A. variegatus* produce both (*S*)-fuscumol and (*S*)-fuscumol acetate (Hughes et al. 2013), whereas male *H. betulinus* produce (*R*)-fuscumol acetate and an 82:18 mixture of the (*R*)- and (*S*)-enantiomers of fuscumol (Vidal et al. 2010). These details will be elucidated as pheromone emissions are collected from the various species, and the components and ratios are fully identified and bioassayed in their naturally occurring ratios.

In summary, the data summarized here, from four consecutive years of bioassays with semiochemically baited traps, provide detailed information on the activity patterns of a substantial portion of the cerambycid community of the eastern United States. Although some of this information was available in very fragmented and largely anecdotal forms from collection records and secondary literature, the results presented here provide hard quantitative data on the abundance, seasonal phenology, and variation in seasonal phenology of a large number of species.

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