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Seasonal flight activity and distribution of metallic woodboring beetles (Coleoptera: Buprestidae) collected in North Carolina and Tennessee

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Abstract

Distribution records and seasonal flight activity information for metallic woodboring beetle (Coleoptera: Buprestidae) species have not been compiled for North Carolina and Tennessee. Institutional, research, and private collections in North Carolina and Tennessee were reviewed to provide seasonal activity data of 5 subfamilies of buprestid beetle species. Label information was checked for 15,217 specimens of 135 species collected between 1901 and 2013 (North Carolina) and between 1934 and 2013 (Tennessee). These collections provided data on adult seasonal activity and county records for 121 species (4,467 specimens) and 105 species (10,750 specimens) from North Carolina and Tennessee, respectively. Two species, *Agrilus carpini* Knull and *A. pensus* Horn, are reported as New State Records for North Carolina. The data reveal key geographic areas in both states where few to no collections have been made, highlighting opportunities to validate species distributions and locations where future collecting efforts can be matched with the occurrence of larval and adult host plant resources. Seasonal activity records will inform future biosurveillance efforts for invasive and endemic pests and facilitate predictions of buprestid species that are likely to be active within the hunting flight season of *Cerceris fumipennis* (Say) (Hymenoptera: Crabronidae) wasps. Activity periods of the buprestids also can focus the management of selected economic pest species to times of the year when treatment efforts, particularly through use of contact insecticides, are likely to be most effective.

Key Words: biosurveillance; *Cerceris fumipennis*; intrastate distribution; jewel beetles; landscape; non-native insects; nursery; pest monitoring

Resumen

Una búsqueda bibliográfica indica que los registros de distribución y la información de actividad de vuelo estacional de las especies de escarabajos metálicos barrenadores de madera (Coleoptera: Buprestidae) no han sido compilados para la Carolina del Norte y Tennessee. Si estuvieran disponibles, esos datos proveerían información valiosa para el futuro de biovigilancia, el moritoreo y manejo de estos insectos económicos y ecológicamente importantes. Para satisfacer esta necesidad, se evaluaron las colecciones institucionales, las de investigación y las colecccciones privadas en Carolina del Norte y Tennessee para proveer datos de actividad estacional de 5 subfamilias de especies de escarabajos buprestidos activos en ambos estados. Se revisaron las etiquetas de 15,010 especimenes en 136 especies de buprestidos recolectadas entre 1901–2013 (Carolina del Norte) y 1934–2013 (Tennessee). Estas colecciones proveen datos de 121 especies (4,467 especimenes) y 106 especies (10,543 especimenes) de Carolina del Norte y Tennessee, respectivamente. Se presentan registros de actividad estacional de los adultos y las colecciones para los condados. Se reportan dos especies de buprestidos, *Agrilus carpini* Knull y *A. pensus* Horn, como nuevos registros estatales de Carolina del Norte. Los datos revelan las **áreas** geográficas clave en ambos estados donde no recolectaron o recolectaron pocos buprestidos, destacando la oportunidad para validar la distribución de las especies y los lugares donde los futuros esfuerzos de recolectar se puede emparejar con la aparición de los recursos de plantas hospederas de larvas y los adultos. Los registros de su actividad estacional informarán los esfuerzos de biovigilancia de plagas invasoras y endémicas en el futuro, y facilitar las predicciones de especies de buprestidos que son propensos a ser activos dentro de la temporada de caza de vuelo de la avispa, *Cerceris fumipennis* (Say) (Hymenoptera: Crabronidae). Los periodos de actividad de los buprestids pueden enfocar el manejo de especies seleccionadas de plagas económicas para **épocas** del año cuando los esfuerzos de tratamiento, en particular, los del uso de insecticidas de contacto, es probable que sean los menos eficaz.

Palabras Clave: biovigilancia; *Cerceris fumipennis*; distribución intraestatal; escarabajos joya; campo; insectos no nativos; viveros; monitoreo de plagas

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Woodboring insects, including metallic woodboring beetles (Coleoptera: Buprestidae), contribute to recycling dead and dying host plant tissues and are an important food resource for avian and mammalian fauna in U.S. forests (Solomon 1985). Woodboring insects are also associated with high levels of host plant injury and economic losses to deciduous shade and flowering trees in commercial nurseries, urban forests, and managed landscapes (Fulcher et al. 2012, Braman et al. 2015). Infestation rates in Tennessee within just one red maple (*Acer rubrum* L.; Sapindales: Sapindaceae) cultivar by the native buprestid *Chrysobothris femorata* (Olivier) were as high as 38% among untreated trees (Oliver et al. 2010). Similar field infestation percentages have been observed in other southeastern U.S. nurseries (Potter et al. 1988; Allen & Alverson 1994; Coyle et al. 2005). Given the broad host plant range of *C. femorata*, as well as other beetles within the *C. femorata* species group (Solomon 1985; Wellso & Manley 2007; Nelson et al. 2008; Hansen 2010; Hansen et al. 2012; Paiero et al. 2012; Hansen et al. in press), large numbers of tree species and cultivars are under significant risk if buprestid species are misidentified, are not monitored properly, or if management efforts are timed poorly (Troxclair 2005; Seagraves et al. 2012; LeBude & Adkins 2014).

In addition to economic threats from native buprestids, non-native buprestid species threaten environmental sustainability of U.S. forests and managed landscapes. Emerald ash borer, *Agrilus planipennis* Fairmaire, occurs now in north-central North Carolina and middle to eastern Tennessee (USDA–Forest Service et al. 2014). The non-native *A. planipennis* threatens timber value of ash trees (*Fraxinus* spp. L.; Lamiales: Oleaceae) in Tennessee and North Carolina, estimated to be worth about $16.06 billion dollars annually (Nowak et al. 2003; USDA–Forest Service et al. 2014). In Tennessee and North Carolina, loss of ash trees would have an impact on local ecology, including survival of native arthropods that are dependent upon the species (Gandhi & Herms 2010). Another non-native buprestid, *Agrilus subrobustus* Saunders, was recently discovered in Tennessee and appears to be associated only with non-indigenous and invasive mimosa trees (*Albizia julibrissin* Durazzini; Fabales: Fabaceae) (Westcott 2007; Hansen et al. 2010; Hoebeke & Wheeler 2011; Hansen et al. 2012). The biology and behavior of *A. subrobustus* remain poorly understood, thus the extent to which this species may become a potential pest or ally in biological control of mimosa remains unclear (Hoebeke & Weeler 2011).

To address these monitoring and management challenges, several efforts have been made to develop flight intercept traps for insect monitoring that are optimized by exploiting visual cues used by buprestid beetle species and other woodboring pests (e.g., Oliver et al. 2002). These approaches, in turn, provided insights into optimizing the attraction of many buprestid species to traps (Hansen et al. 2012; MacRae & Basham 2013) and have led to widespread deployment of the purple prism traps currently used to monitor populations of emerald ash borers (Francese et al. 2010, 2013). Buprestid beetles are also the primary prey item of the ground-nesting wasp *Cerceris fumipennis* (Say) (Hymenoptera: Crabronidae). Utilizing this species' hunting behavior has become an effective biosurveillance tool in efforts to detect the non-native *A. planipennis* as well as other economically important buprestid pest species (Marshall et al. 2005; Careless 2009; Careless et al. 2009), and to survey native buprestid faunas (Swink et al. 2013; Careless et al. 2014).

Evaluation of several years of trap optimization and efficacy trials, together with regional field trapping for key woodboring pests, revealed gaps in our knowledge regarding regional activity periods for buprestid species that are the primary economic pests of woody ornamental plants (e.g., *Chrysobothris* species). Distribution patterns across both states where these species could be expected to occur were not known (Hansen et al. 2012). Moreover, it remained unclear whether the activity period of other species of buprestid beetles overlapped with the hunting flight season of the relatively short-lived adult *C. fumipennis* (Marshall et al. 2005; Careless et al. 2014).

To address these knowledge gaps, institutional, research, and teaching collections as well as museums and personal collections in both North Carolina and Tennessee were accessed to assemble available label data to determine species location and distribution, as well as seasonal flight activities of adult buprestid beetles. The outcome of this effort will provide baseline data for documentation of species diversity, help direct field collection efforts to resolve on-going challenges related to species taxonomy and phylogenies within difficult species groups, assist with documentation of invasive species, and fine-tune the use of *C. fumipennis* as a tool for biosurveillance of pest buprestids.

Supplementary material for this article in Florida Entomologist 98(2) (June 2015) is online at http://purl.fcla.edu/fcla/entomologist/browse. Therefore, the supplementary table is referred to in this article as Suppl. Table 1, and supplementary figures are referred to herein as Suppl. Figs. All supplementary figures are displayed online in color.

Materials and Methods

The data for this report were derived from specimens collected in conjunction with a series of season-long experimental trials conducted by Tennessee State University–affiliated authors and cooperators with the goal of optimizing trap type and color to enhance attraction of woodboring insects to static traps (Oliver et al. 2002, 2004), and by Hansen (2010) during the process of obtaining specimens needed for phylogenetic analyses within closely-related taxa among buprestid species. Data from these research efforts are taken from reports in progress; thus details about trap type and trap color or kairomone and lure efficacy are not reported herein. Extended seasonal collections were made in regions of middle or eastern Tennessee at about weekly intervals from Apr 1 to Aug 28, 2001; Apr 6 to Oct 7, 2002; May 5 to Sep 2, 2003; Apr 12 to Aug 9, 2004; May 2 to Aug 15, 2005; May 2 to Aug 15, 2006; Jun 5 to Jul 21, 2009; Jun 8 to Aug 5, 2010; Jun 17 to Aug 18, 2011; Apr 9 to Sep 10, 2012; and May 11 to Sep 10, 2013. In North Carolina, biosurveillance efforts targeting *A. planipennis* yielded buprestid beetle captures collected from *C. fumipennis* wasps during Jun 2 to Jul 27, 2009; Jun 4 to Jul 28, 2010; Jun 2 to Jul 13, 2011; and May 21 to Jul 13, 2012 (Nalepa et al. 2012, 2013; Swink et al. 2013, 2014). Collection records for many of these studies included trap yield results for deployment durations spanning several days, thus data for individual specimens were pooled within 1 of 4 weeks for each month.

Data compiled from labeled specimens from each state included collection date, county data, other locality information provided, and collector. Specimens may have been taken by sugar or ethanol baited traps (Lindgren and others), light traps, sticky panel traps, malaise traps, vane traps, canopy fogging, and sweep-net or hand collections. Label dates provided for specimens that emerged from infested trunk, stem, firewood, and branch sections were not included among seasonal activity charts, but species were listed among county records for each state. Dashed vertical lines (at May and Jul) are presented on the seasonal activity grid and indicate approximate flight activity period (in North Carolina) for *C. fumipennis* wasps. Species collected by *C. fumipennis* wasps in North Carolina during biosurveillance efforts (Swink et al. 2013, 2014) are noted with an asterisk (Figs. 1A, 1B, and 1C; Suppl. Fig. 1A–C).

Specimens also were examined in the collections of the University of Tennessee Entomology and Plant Pathology Insect Museum [ECUT] and the Great Smoky Mountains National Park [GSNP]. The latter included results of tree sampling taken at multiple times across 2 or more seasons from targeted tree species, such as eastern hem-

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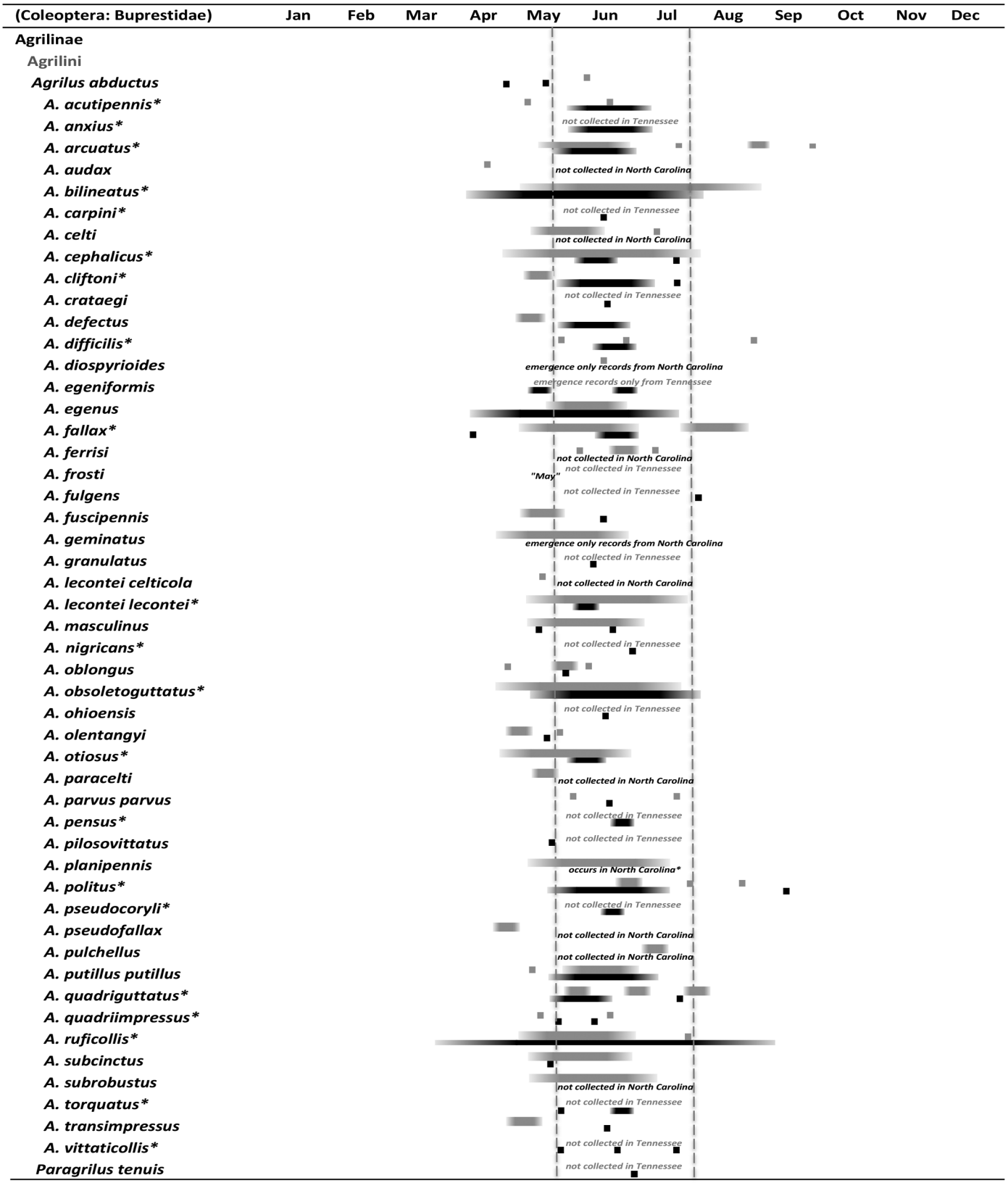


Fig. 1A. Seasonal flight activities recorded for Agrilinae: Agrilini metallic woodboring beetle species collected across North Carolina (1901–2013) and Tennessee (1934–2013). Collection records frequently included trapping yield results from multi-day deployments; thus, data for individual specimens were pooled within 1 of 4 weeks for each month. Dated records for specimens with labels that noted specimen emergence from infested trunk, stem, firewood, and branch sections are not included within the seasonal ranges presented. Dashed vertical lines (at May and Jul) indicate approximate flight activity period (in North Carolina) for *Cerceris fumipennis* (Say) (Hymenoptera: Crabronidae) wasps. Asterisks indicate species collected by the wasps during biosurveillance in North Carolina (Nalepa et al. 2013; Swink et al. 2013, 2014). This figure is displayed in color online at http://purl.fcla.edu/fcla/entomologist/browse

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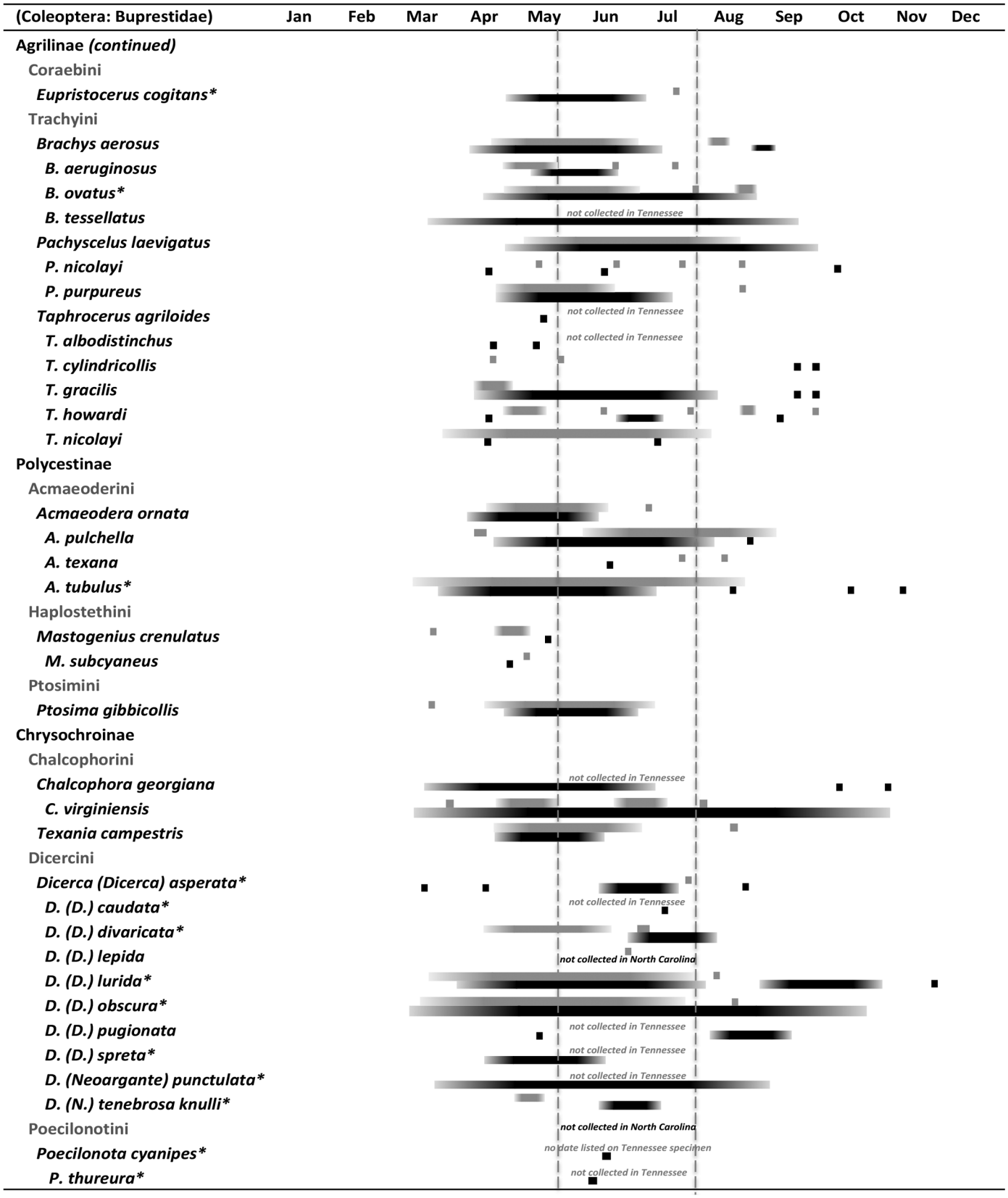
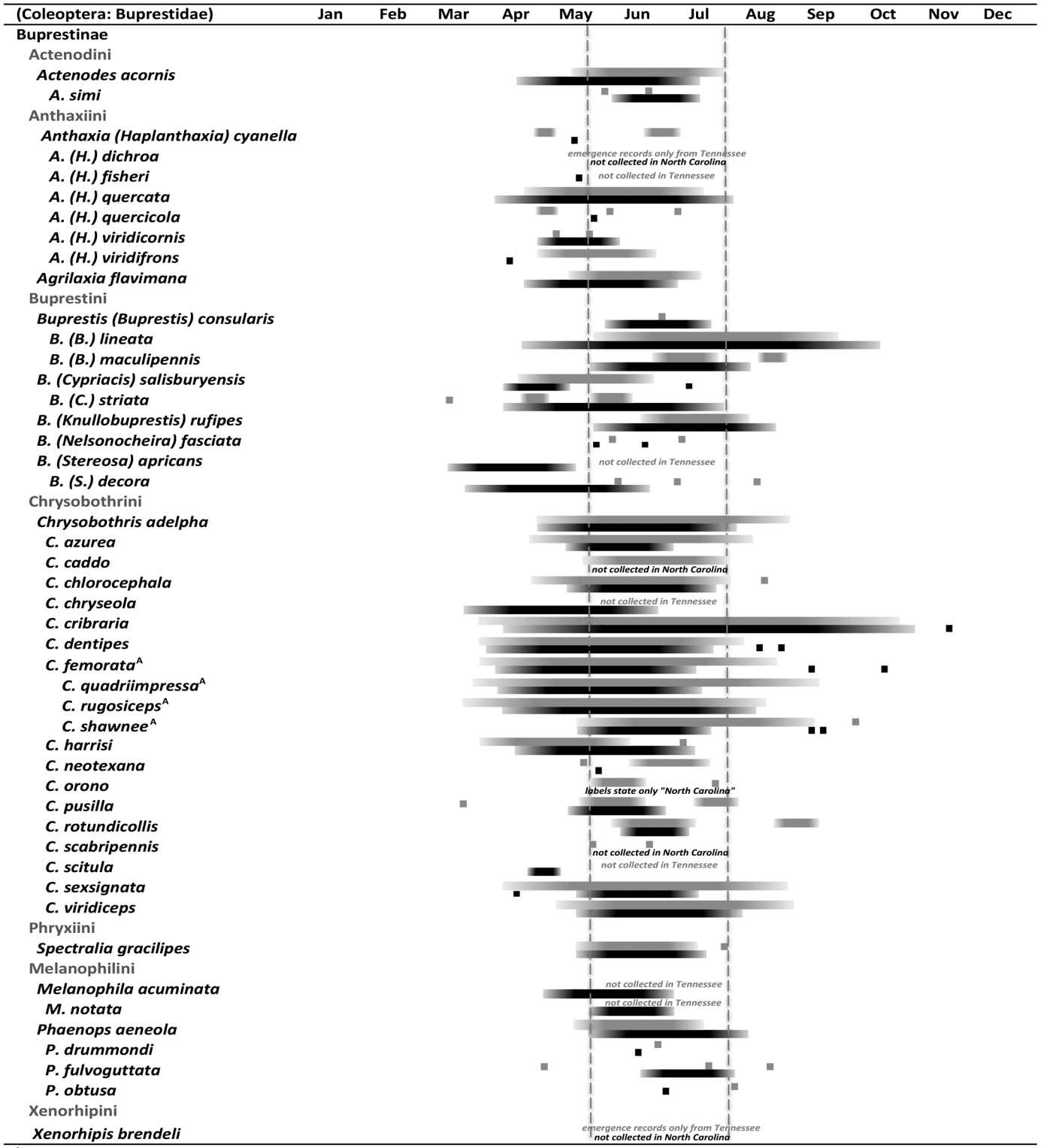


Fig. 1B. Seasonal flight activities recorded for Agrilinae (Coraebini and Trachyini), Polycestinae, and Chrysocrhoinae metallic woodboring beetle species collected across North Carolina (1901–2013) and Tennessee (1934–2013). Collection records frequently included trapping yield results from multi-day deployments; thus, data for individual specimens were pooled within 1 of 4 weeks for each month. Dated records for specimens with labels that noted specimen emergence from infested trunk, stem, firewood, and branch sections are not included within the seasonal ranges presented. Dashed vertical lines (at May and Jul) indicate approximate flight activity period (in North Carolina) for *Cerceris fumipennis* (Say) (Hymenoptera: Crabronidae) wasps. Asterisks indicate species collected by the wasps during biosurveillance in North Carolina (Nalepa et al. 2013; Swink et al. 2013, 2014). This figure is displayed in color online at http://purl.fcla.edu/fcla/entomologist/browse

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[A] Anatomical features, particularly among male specimens, may differentiate these members of the *Chrysobothris* species group into cohorts that could represent individual species, though with noted geographic variations in form (Wellso and Manley 2007). Yet, analyses of COX I nuclear and arginine kinase mitochondrial genes were unable to classify representative members as monophyletic species (Hansen et al. 2015). Specimens presented here of anatomically grouped individuals illustrate seasonal overlap of adult flight activities in both North Carolina and Tennessee.

Fig. 1C. Seasonal flight activities recorded for Buprestinae metallic woodboring beetle species collected across North Carolina (1901–2013) and Tennessee (1934–2013). Collection records frequently included trapping yield results from multi-day deployments; thus, data for individual specimens were pooled within 1 of 4 weeks for each month. Dated records for specimens with labels that noted specimen emergence from infested trunk, stem, firewood, and branch sections are not included within the seasonal ranges presented. Dashed vertical lines (at May and Jul) indicate approximate flight activity period (in North Carolina) for *Cerceris fumipennis* (Say) (Hymenoptera: Crabronidae) wasps. Asterisks indicate species collected by the wasps during biosurveillance in North Carolina (Nalepa et al. 2013; Swink et al. 2013, 2014). This figure is displayed in color online at http://purl.fcla.edu/fcla/entomologist/browse

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lock (*Tsuga canadensis* [L.]; Pinales: Pinaceae) (Buck 2004), southern magnolia (*Magnolia grandiflora* L.; Magnoliales: Magnoliaceae) (Werle 2002), tulip poplar (*Lirodendron tulipifera* L.; Magnoliales: Magnoliaceae) (LaForest et al. 2000), and northern red oak [*Quercus rubra* L.; Fagales: Fagaceae] (Trieff 2002). Other records that included seasonal activity and county occurrence data were retrieved from published reports (Nicolay & Weiss 1923; Fisher 1928; Knull 1930, 1934; Evans 1957; Dozier 1955; Hespenheide 1973; Nelson & Westcott 1976; Nelson 1978; Westcott et al. 1979; Nelson et al. 1981, 1996; Hespenheide 2003; MacRae & Nelson 2003; Wellso & Manley 2007; MacRae & Basham 2013).

Collection depositories [brackets] with specimen data that were evaluated and integrated into this report include (Evenhuis & Samuelson 2007, or as acknowledged): [CUIC], [ECUT], [EDNC], [GSNP], [FSCA (repository for G.H. Nelson collection)], [LSAM], [MCZ (repository for the G. H. Horn collection, formerly housed by the Pennsylvania Academy of Natural Sciences)], [NCSU], [TSRS], [UGCA], and [WFBM]. [UGCA] had also recently acquired and made available the arthropod collection previously maintained at the Memphis State University (now, University of Memphis). Records of observed specimens and published accounts from additional institutional and personal collections that were incorporated included those of: JAHC = Jason A. Hansen, JEWC = James E. Wappes, JMBC = Jason M. Basham, JPBC = Joshua P. Basham, NNYC = Nadeer N. Youssef, RLWE = Richard L. Westcott, SGWC = Stanley G. Wellso, TCMC = Ted C. MacRae, TTUC = Tennessee Technological University, and WEKC = William E. Klingeman.

To reduce inherent bias, an optimal method to approach a survey like this would no doubt include extended-season sampling across all regions of each state for several years. Economic and labor constraints limit the feasibility of this aim. Regardless, we expect this study will highlight poorly-studied regions across both states; thus, future research and collection can focus on these regions.

Results

Identities and label records were examined for 15,217 specimens, representing 135 different buprestid beetle species taken between 1901 and 2013 (North Carolina) and between 1934 and 2013 (Tennessee) and used to compile seasonal activity and distributional records for each species. Collections and records assessed from North Carolina yielded 121 buprestid species (4,467 specimens), and 105 species (10,750 specimens) were reported from Tennessee (Suppl. Table 1). Among the 100 North Carolina and 96 Tennessee counties, collection records included specimens taken in 96 (96%) and 54 (56%), respectively (Suppl. Table 1). To date, no buprestid records were found for Camden, Chowan, Hertford, or Perquimans Counties in northeastern North Carolina. Slightly less than one-half of Tennessee counties were unrepresented in buprestid beetle collection records. For most counties in both states, documented collection records represented a single to very few buprestid species (Figs. 2 and 3; Suppl. Figs. 2 and 3).

The most intensive collection activity in Tennessee focused around the University of Tennessee – Knoxville campus and the Great Smoky Mountains National Park, as well as the Otis L. Floyd Nursery Crops Research Center in McMinnville, Tennessee. The Otis L. Floyd Nursery Crops Research Center currently maintains the largest single collection of buprestids in Tennessee (Hansen et al. 2010). Most specimens collected in North Carolina were from counties adjacent to North Carolina State University and counties that were surveyed annually as part of the *C. fumipennis* biosurveillance program (Swink et al. 2013). Species tallies reported within individual counties (Fig. 3; Suppl. Fig. 3) were also highest in counties containing North Carolina State University–managed forests, research and Extension facilities, and counties containing readily accessible and unique ecosystems, like the Carolina Sandhills region spanning Moore County.

Biosurveillance with *C. fumipennis* wasps during 2013 yielded 2 New State Records for North Carolina. A single *Agrilus* Knull (1923) was collected from a foraging *C. fumipennis* wasp in Wake County, Raleigh, Jaycee Park, 8-VI-2010, det. S. Paiero. Seven specimens of *Agrilus pensus* Horn (1891) were taken in Surry County, Mt. Airy, Meadowview Middle School, 13-VI (1), 26-VI (5), 8-VII-2013 (1), det. Joshua P. Basham. All *A. carpini* and *A. pensus* specimens are held at [EDNC].

Discussion

Distributional records and seasonal flight activity charts for the buprestid fauna in North Carolina and Tennessee are expected to help

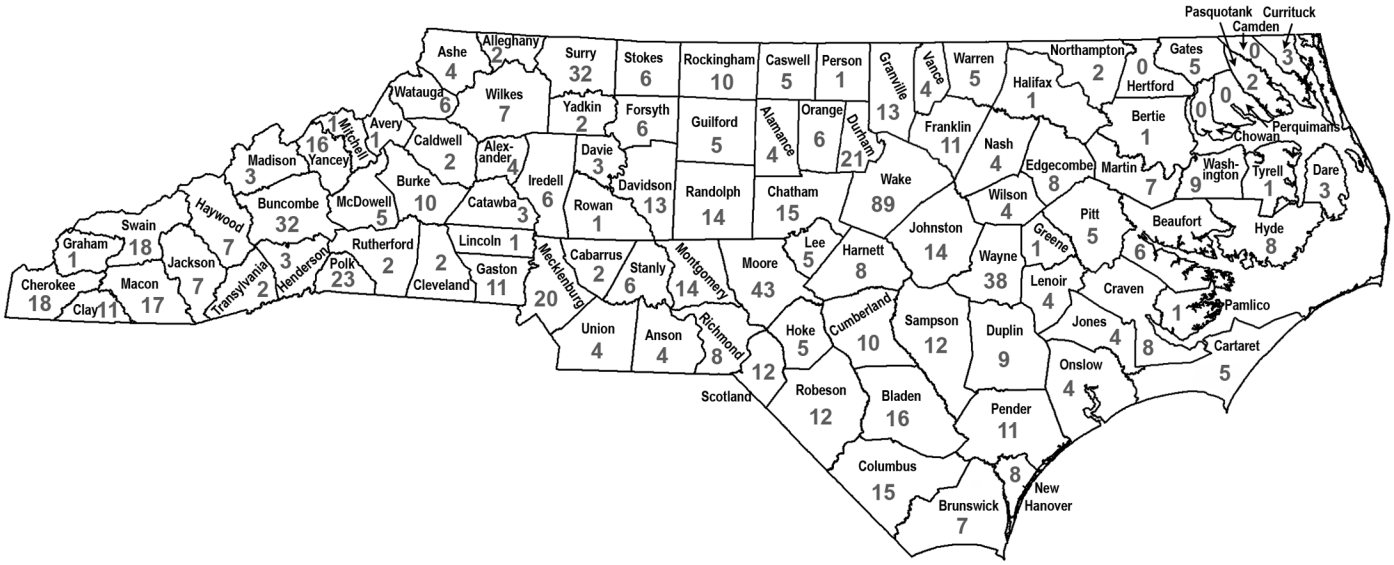


Fig. 2. Tallies within each North Carolina county indicate the total buprestid species recorded from specimen label records spanning 1901 to 2013. When presented across North Carolina, species yields indicate areas of greatest and least collection activity and highlight regions of future collection interest. This figure is displayed in color online at http://purl.fcla.edu/fcla/entomologist/browse

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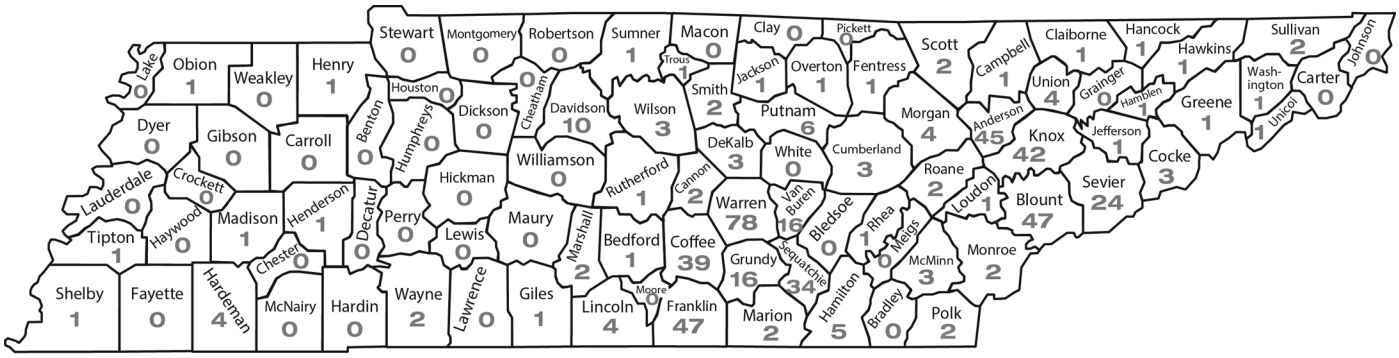


Fig. 3. Tallies within each Tennessee county indicate the total buprestid species recorded from specimen label records spanning 1934 to 2013. When presented across Tennessee, species yields indicate areas of greatest and least collection activity and highlight regions of future collection interest. This figure is displayed in color online at http://purl.fcla.edu/fcla/entomologist/browse

document potential environmental and economic impacts presented by non-native buprestid beetle species to these states. Since the 2008 inception of the *C. fumipennis* biosurveillance program in North Carolina, more than 2,300 buprestids, including 13 new state records with the 2 reported herein, have been collected from the wasp in 26 counties (MacRae & Basham 2013; Swink et al. 2013, 2014). In a similar timeframe, host plant–directed scouting and improvements to buprestid trapping using experimental panel traps and other techniques have yielded 48 new state records for Tennessee (Hansen et al. 2010, 2012; MacRae & Basham 2013).

Although biosurveillance efforts have not been undertaken in Tennessee, monitoring *C. fumipennis* wasp nest sites has been effective in North Carolina for detecting many infrequently collected and uncommon buprestid species, particularly when high-density nesting aggregations of the wasp can be found (Swink et al. 2013, 2014). We anticipate that the seasonal flight activity and regional occurrence records presented herein for buprestid beetles will aid future biosurveillance efforts, and that *C. fumipennis* can help to elucidate seasonal activity patterns of infrequently collected or uncommon species. Future collections are needed to help validate range distributions of species not collected in either North Carolina or Tennessee. Opportunities exist to document the occurrence of *Chrysobothris scabripennis* Gory & Laporte, *Chrysobothris caddo* Wellso & Manley, and *Xenorhipis brendeli* LeConte, as well as to clarify range distribution *Chrysobothris orono* Frost in North Carolina. Monitoring efforts may also document *Chrysobothris chrysoela* (Illiger) in Tennessee and *Chrysobothris verdigripennis* Frost in both states. When plotted across counties for each state (Figs. 2 and 3; Suppl. Figs. 2 and 3), collection data reveal large portions of the state where buprestid collections are infrequent to absent. Future trapping efforts are expected to be most productive when our maps are paired with ecoregional distribution records of likely larval host plants (see Griffith et al. 1998, 2002).

In addition to the success of using *C. fumipennis* to locate emerald ash borer in Connecticut (Rutledge et al. 2013), the wasp might be used for monitoring and detecting other invasive buprestid species, such as *A. subrobustus* and *Agrilus sulcicollis* Lacordaire (Marshall et al. 2005; Careless 2009; Careless et al. 2009; Haack et al. 2009), due to potential overlapping flight activity periods of these beetles and the wasp. In North Carolina however, population densities of *C. fumipennis* are lower than those observed in the northeastern US (Nalepa et al. 2012). Efforts to employ biosurveillance in the North Carolina counties of Granville, Person, Vance, and Warren, where *A. planipennis* has been detected by other means, were not successful, likely due to failure in these counties of finding sites with a sufficient number of *C. fumipennis* nests (CA Nalepa & W Swink, personal observation). Still, *C. fumipennis* has been successful in detecting *Agrilus anxius* Gory, which had not previously been reported in North Carolina (Swink et al. 2013). We anticipate that *C. fumipennis* will play a future role in surveys of eastern US forests and landscapes for non-native pests of potential concern, such as the goldspotted oak borer, *Agrilus auroguttatus* Schaeffer (Coleman & Seybold 2009; Hespenheide et al. 2011), which is currently distributed only in Arizona, California, and Mexico. The activity period of *C. fumipennis* in North Carolina overlaps with most documented buprestid flight periods (Figs. 1A, 1B, and 1C; Suppl. Fig. 1A–C).

The genus *Chrysobothris* Eschscholtz includes several readily-confused members that are frequently pooled within a *C. femorata* species group, or complex. Within the complex, differing anatomical characters, including integument color, elytral pattern, and form of the male genitalia are used to differentiate between species in the complex (Fisher 1942; MacRae 2001; Wellso & Manley 2007). When populations of these putative species are examined across a wider geographic range, intermediary forms of these character states may be observed, confounding even the ability of experts to accurately identify some of them (Wellso & Manley 2007; Hansen 2010; Paiero et al. 2012; Hansen et al. in press). In fact, molecular analyses of nuclear and mitochondrial genes have been unable to resolve *C. femorata* species group identities between specimens grouped by anatomical characters as *C. femorata* (Olivier), *C. rugosiceps* Melsheimer, *C. quadriimpressa* Melsheimer, or *C. shawnee* Wellso & Manley. These species group members emerged as polyphyletic in maximum likelihood phylograms based on morphological characters and concatenated analyses of cytochrome oxidase I and arginine kinase genes (Hansen et al. in press). By contrast, *C. adelpha* Harold and *C. viridiceps* Melsheimer, along with *C. wintu* Wellso & Manley distributed in the western US are supported as monophyletic species and possess anatomical differences in their male genitalia that may influence interspecific functionality (Hansen et al. in press). Observations presented here help support working hypotheses that some *C. femorata* species group members may be interbreeding (Fisher 1942; Hansen 2010; Hansen et al. in press). Members of this complex demonstrate overlapping seasonal flight activity (Fig. 1C; Suppl. Fig. 1A–C), are active within many of the same counties in both North Carolina and Tennessee (Suppl. Table 1), and share *Quercus* species as plant hosts (e.g., MacRae 2001; Nelson et al. 2008; Hansen et al. 2011, 2012; Paiero et al. 2012).

Distributional records will be helpful for guiding collections needed for future phylogenetic research efforts to clarify species identities within other closely related taxa and within the *C. femorata* group, and to substantiate evidence of interbreeding. Flight activity records also can guide commercial pest management strategies that are necessary

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to limit economic and aesthetic losses, for example by members of the *C. femorata* species group that are active in deciduous shade tree production systems. Except *A. bilineatus* and *Agrilus ruficollis* (F.), adults of most *Agrilus* species are active from late spring until mid-summer. Efforts in late summer to monitor or manage adult *Chrysobothris* pests in nurseries and landscapes are unlikely to be effective as adult populations decline, particularly if employing contact and short-residual insecticides that do not reach larvae feeding beneath the bark.

Finally, despite the relatively recent trapping activity conducted mostly from mid-Apr through Aug in Tennessee and Jun and Jul in North Carolina across several years, collection records for many species remain limited to relatively few individuals and specimens opportunistically or serendipitously collected independent of seasonal trapping efforts. We caution, therefore, that inferences made about potential voltinism for species presented here may not be valid when evaluating the seasonal activity data presented for each state.

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