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Sampling Buprestidae (Coleoptera) in Washington state with *Cerceris californica* Cresson (Hymenoptera, Crabronidae)

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Abstract

The beetle-hunting habits of ground nesting wasps in the genus *Cerceris* Latreille have been recently exploited as a survey technique for exotic and native Buprestidae, particularly *Agrilus planipennis* Fairmaire (the emerald ash-borer). While such methods have been developed for the wide-ranging eastern *Cerceris fumipennis* Say, the survey potential of western buprestid-hunting *Cerceris* spp. has not been explored. *Cerceris californica* Cresson is the most well-studied of the western buprestid feeders, and the only one known to occur in Washington state. Here we report the results of surveys conducted in Washington in 2012–2013 for *C. californica* colonies, and numbers of buprestid beetles collected from monitored colonies. Eight *C. californica* colonies were found through visual search of 228 baseball fields and sandy clearings, but only four were large enough to monitor. Fifty-four beetles were recovered from the four colonies, comprising five native species. Four of these are new prey records for *C. californica*, and one (*Chrysobothris quadriimpressa* Gory & Laporte) is newly recorded from Washington. *Cerceris californica* colonies do not appear to be large or common enough in Washington to be a significant exotic buprestid survey strategy. However, even the limited monitoring resulted in more buprestid captures than nearby purple sticky traps, and monitoring *C. californica* nests may be a locally useful supplement for general buprestid surveys.

Keywords

Exotic species, survey

Introduction

The recent spread of two exotic metallic woodboring beetle species (Coleoptera, Buprestidae) in parts of North America has resulted in widespread tree mortality and looming long-term changes in ecological communities. Both are in the speciose genus *Agrilus*, which includes species capable of feeding upon and potentially killing live, healthy trees. The emerald ash borer (EAB), *A. planipennis* Fairmaire, 1888, was first detected in North America in 2002 (Cappaert et al. 2005, Poland and McCullough 2006), although it may have been present for many years prior (Kovacs et al. 2009). To date, the beetle has been detected in 23 states and two provinces in the northeastern United States and Canada (http://tinyurl.com/lyaka3y, accessed April 18, 2014). The congener goldspotted oak borer, *A. auroguttatus* Schaeffer, 1905, (in some past literature treated under *A. coxalis* Waterhouse, 1889, a Mexican and Central American species) has been introduced into southern California from its native range, probably from southeastern Arizona or northern Mexico, although in Mexico it has been recorded only from Baja California Sur. It has caused extensive mortality among oak species and has been steadily expanding its range northward since 2002 (Coleman and Seybold 2008, Coleman et al. 2012).

There is considerable need to effectively monitor for these species and other exotic woodborers to maximize the possibility of early detection and eradication of newly established populations. Methods for detecting and monitoring *Agrilus planipennis* and *A. auroguttatus* include visual survey for impacted trees, use of trap trees, twig sampling, sticky ash leaves, and large sticky traps baited with plant volatiles or beetle decoys (Francese et al. 2008, Poland et al. 2010, McCollough et al. 2010, McCollough et al. 2011, Ryall et al. 2011, Crook et al. 2012, Domingue et al. 2012). Developing lures and traps that are effective at detecting *A. planipennis* at low densities has been an ongoing challenge, and an ideal trap design remains elusive. The current USDA-APHIS EAB trapping protocols employ large prismatic purple sticky traps and a sampling map derived from a risk-based model emphasizing high-risk locations. Traps are armed with volatile lures and deployed in the canopy of appropriately sized *Fraxinus* trees, ideally within the model-generated trapping cells (USDA-APHIS 2013).

An alternative buprestid survey and monitoring method developed in the eastern states and provinces exploits the biology of a ground-nesting wasp in the family Crabronidae, *Cerceris fumipennis* Say, 1837. The genus *Cerceris* includes hundreds of species worldwide, adults of which hunt and collect various beetle groups as a larval food source (Bohart and Menke 1976). The majority of species for which prey data are known target Curculionidae, with fewer species preying upon Tenebrionidae, Bruchidae, Chrysomelidae, and Buprestidae. In North America, Buprestidae are the primary prey items for the five species in Scullen's (1965) Group II. *Cerceris fumipennis* is the most thoroughly studied of this group, occurring from Ontario to Florida and west into Texas and Wyoming. More than 100 species of buprestids have been recorded as prey items, including adventitious species with which it shares no evolutionary history (Scullen and Wold 1969, Rutledge et al. 2011, Swink et al. 2013, Hellman and Fierke 2014).

Figure 1. A *Cerceris californica* nest **B** Adjacent *Philanthus gibbosus* (left) and *C. californica* (right) nests.

In 2005, new provincial distribution records for several buprestid species collected from foraging *Cerceris fumipennis* in Ontario launched a research program to develop a buprestid detection and monitoring tool using the wasp, sometimes dubbed "biosurveillance" (Careless et al. 2014). The beetle-hunting habits of the wasp were already well known, but it had not previously been used to investigate the occurrence, distribution, or spread of buprestid species. Careless et al. (2014) developed a thorough methodology for using *C. fumipennis* to detect *A. planipennis*, which are readily captured by the wasps, and several eastern states and provinces have successfully implemented wasp-based monitoring programs. The first *A. planipennis* recorded in Connecticut was collected from a foraging wasp in 2012, concurrent with a capture on a purple sticky trap (Rutledge et al. 2013).

The other four North American *Cerceris* species known or presumed to prey upon Buprestidae occur in the western states and provinces, and northern Mexico (Scullen 1965, Bohart and Grissell 1975). Of these, *C. californica* Cresson, 1865, ranges from British Columbia south into Mexico, and east to Texas (where it occurs with *C. fumipennis*). Females are active from at least mid-June through August, when they construct simple nests in compacted sandy soil (Fig. 1) and provision them with paralyzed buprestid beetles. Although less studied than *C. fumipennis*, it remains one of the better understood *Cerceris* species in North America, with 29 recorded prey species (Linsley and MacSwain 1956, Evans and Rubink 1978, Nelson and Westcott 1991, Davidson 2003). By comparison, few prey records are documented for the other three species attacking Buprestidae (Davidson 2003, Looney and Westcott unpublished data).

This project explored adapting the eastern sampling methodology to *Cerceris californica* in Washington to examine the potential utility of this survey method. We report on survey results for *C. californica* nest sites in Washington and new buprestid prey records from monitored nests. Data are limited, but we also compare the location of monitored nests and beetles recovered from *C. californica* with the location and results of 2013 EAB trapping with purple sticky traps. The potential contribution of *C. californica* to exotic buprestid monitoring is evaluated in the context of the *C. fumipennis* program in the east, using criteria described in Careless et al. (2014).

Methods

There are no published locations of *Cerceris californica* nest sites in Washington. Potential wasp range was inferred from Scullen (1965) and specimens housed at Washington State University, the University of Idaho, the University of California, Riverside, and Oregon State University. In Washington, wasps have been collected only east of the Cascade Range, from localities such as White Swan, Prosser, Moses Lake, Buena, Wawawai, and Lake Paha. All of these specimens were collected from flowers or at large, not from nesting sites. Surveys for *C. californica* nesting aggregations were made in Washington between July 7–25 2012, and May through July 2013 (Fig. 2). Possible *C. californica* burrows can be identified by an evenly distributed ring of excavated soil, or tumulus (Linsley and MacSwain 1956; Fig. 1).

Following Careless et al. (2014) and Nalepa et al. (2012), nest search concentrated primarily on baseball diamonds in hope of maximizing opportunities to find large colonies that would lend themselves to buprestid monitoring. Baseball diamonds are often occupied by *Cerceris* colonies, and offer several benefits for *Cerceris* survey. They represent large areas of consistent habitat for wasps and are easily located using online satellite imagery (Nalepa et al. 2012). Baseball diamonds may not be the only occupied habitat in a region, but when wasps are locally present in an area they are more easily found in ball fields than other habitat (e.g. dirt roads/trails, exposed earth) (Careless et al. 2014, Hellman and Fierke 2014). By focusing on easily-located baseball diamonds, towns may be relatively quickly surveyed for wasps. Baseball diamonds are typically

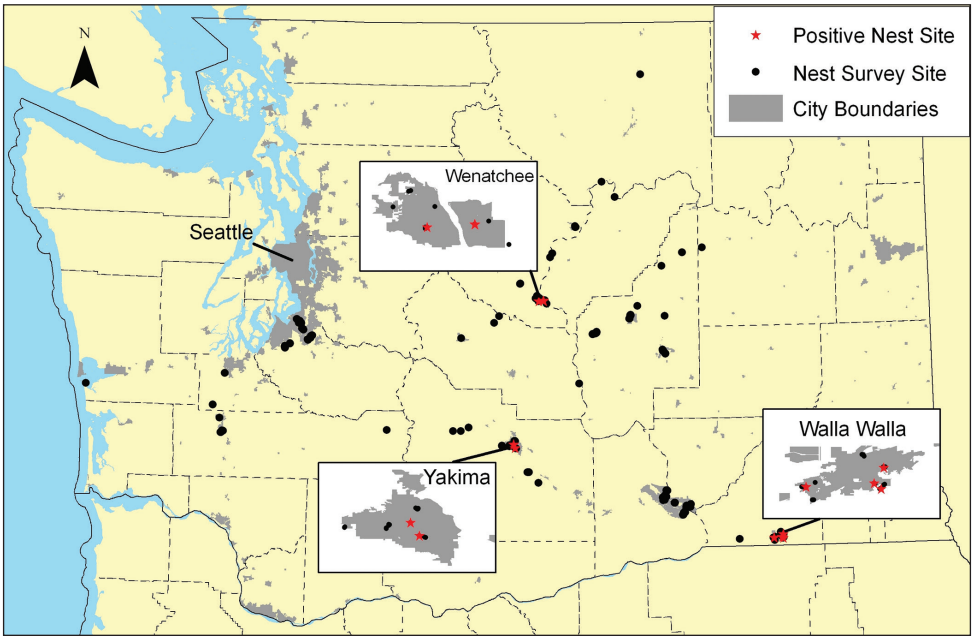

Figure 2. *Cerceris californica* survey sites, 2012–2013.

located on public land (schools, parks) and are therefore usually accessible to government and citizen surveyors. Since they are located in parks, there are often numerous tree species planted relatively close, which provide good habitat for buprestid beetles. Drawbacks to focusing on baseball fields include potentially high levels of maintenance and disturbance, which may deter *Cerceris* nesting, and unfavorable soil formulations (Nalepa et al. 2012). Some campgrounds, dirt roads, and vacant lots were also included in the survey.

Beetle collection followed the methodology described in Careless et al. (2014) for *Cerceris fumipennis*. First, aggregations were censused and the location of all *Cerceris* nests was mapped. The threshold for monitoring was set at ~15 burrows (Table 1). Any beetles found on the ground while surveying were collected. "Careless collars", plastic tabs with holes, were placed over each nest to mark location and impede entry by wasps returning with beetle prey (Careless et al. 2014). Frequency of wasps returning with

Table 1. Monitoring dates, wasp colony size, and beetles capture (– indicates no monitoring).

Site	Date	Duration (hrs)	Num. of Nests	Buprestids Recovered	
Yakima, Franklin Park				Wasp	Ground
	5 Jul 2012	1	8	0	0
	12 Jul 2012	2	21	5	2
	26 Jul 2012	3.5	13	8	0
	2 Aug 2012	2.5	1	1	1
	15 Aug 2012	4	1	0	0
	14 May 2013	–	0	–	–
	17 Jun 2013	2	8	0	0
	3 Jul 2013	2	33	14	1
	9 Jul 2013	2	16	1	0
	25 Jul 13	2	7	1	0
	29 Jul 2013	2	10	0	0
	2 Aug 2013	1	0	0	0
Yakima, Lewis & Clark Middle School					
	6 Jul 2012	2	15	2	2
	12 Jul 2012	3	24	8	3
	2 Aug 2012	2	2	0	0
	16 Aug 2012	1	0	0	0
	14 May 2013	–	0	–	–
	17 Jun 2013	1	6	0	0
	3 Jul 2013	2	18	0	0
	9 Jul 2013	2	10	0	0
	25 Jul 2013	1	12	0	1
	29 Jul 2013	1	11	0	0
	2 Aug 2013	1	4	0	0
Wenatchee, Eastmont Community Park					
	1 Aug 2012	3	7	3	0
Walla Walla, Roosevelt Park					
	19 Jul 2012	1	>20	1	0
	22 Aug 2012	3	5	0	0

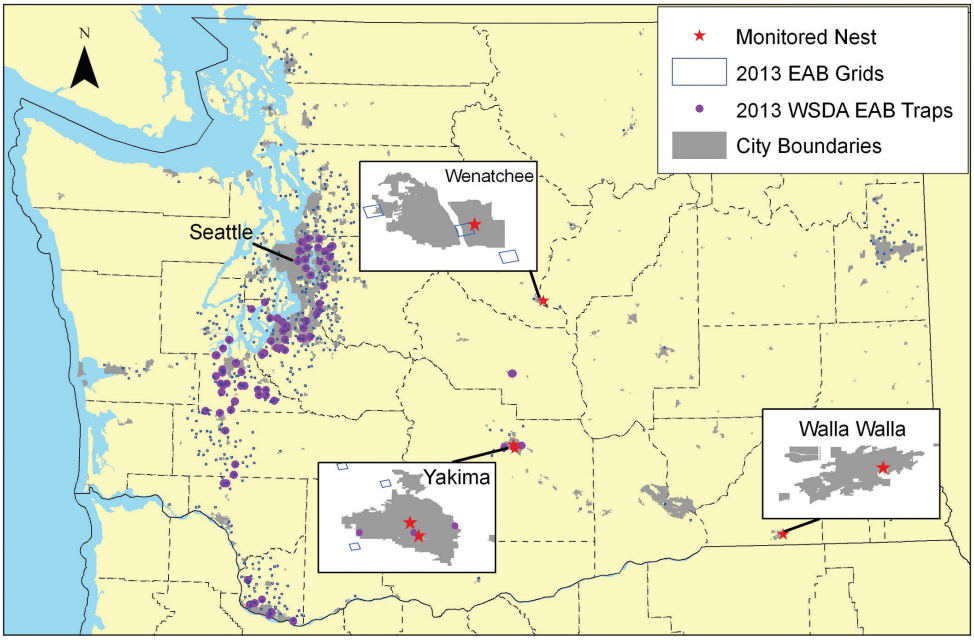

Figure 3. Monitored *Cerceris californica* colony locations compared with 2013 EAB grids and purple prism trap locations.

and without beetle prey was recorded. Beetles were collected from wasps returning to the nest primarily by capturing them with a net. Wasps occasionally dropped the beetle they were carrying, and it was retrieved at that time. All buprestid specimens were retained. Beetles collected in 2012 were weighed and their length measured on the collection day, or immediately frozen and weighed soon after. All buprestid specimens were identified by one of us (RLW). The locations of confirmed colonies were compared with the 2013 USDA-APHIS EAB trapping cells and purple prism trap locations in 2013 (Fig. 3). Beetles retrieved in 2013 were also compared with beetles captured on four purple prism traps nearby, which were deployed from June 28 until 25 September, 2013. Three traps were located in Yakima, and one near Ellensburg (Fig. 3).

Results

In total, 228 baseball diamonds or sandy clearings were inspected for *Cerceris californica* in 2012 and 2013 (Fig. 2). Survey during 2012 detected eight *C. californica* colonies. Of these, only four (located in the cities of Yakima, Wenatchee, and Walla Walla) were robust enough to support monitoring in 2012 (Fig 2). One of these had only seven burrows, but was included due to the general paucity of colonies (Table 1). Only the two large colonies located in Yakima were monitored in 2013. Observed nest density ranged from 1–24 nests in 2012, and from 1–34 in 2013 (Table 2). No colonies

Table 2. Species of Buprestidae collected from *Cerceris californica* during July–August 2012, and July 2013

Beetle Species	Number captured / Percent of total prey	State Record	Prey Record
Agrilus granulatus (Say, 1823)	1 / 1.9		+
Agrilus politus (Say, 1825)	7 / 13		
Chrysobothris nixa Horn, 1886	4 / 7.4		+
Chrysobothris quadriimpressa Gory & Laporte, 1837	4 / 7.4	+	+
Phaenops intrusa (Horn, 1882)	38 / 70.3		+

were located within one of the 2013 EAB trapping cells. The colony in Wenatchee was within a few hundred meters of the nearest trapping cell, and the colonies in Yakima within 10 km (Fig 4). Although not located within a cell, one purple prism trap in Yakima was located within 1.6 km of two *C. californica* colonies.

Cerceris californica activity varied widely between sites and days, from a low of zero wasps observed to a returning wasp observed every 4 minutes. Beetles collected from foraging wasps varied similarly, from 0–7 beetles recovered per hour of monitoring. In 2012, 36 beetles were collected during 28 hours of monitoring; 7 dropped beetles and 29 taken from wasps. In 2013, 18 beetles were collected over 19 hours of monitoring; 2 dropped beetles and 16 taken from wasps. No Buprestidae were captured on purple prism traps in the Yakima or Wenatchee area in 2013.

Beetle weights in 2012 ranged from 5.2 mg to 52.3 mg, and length between 5.21 mm and 10.4 mm. The lightest beetle was a dropped specimen, which appeared to be desiccated. Excluding this specimen, average weight was 19.0 mg, and the average length was 7.80 mm. Over both years five buprestid species were collected in Washington, four of which are new prey records for *Cerceris californica* (Table 2). One of these, *Chrysobothris quadriimpressa* Gory & Laporte, 1837, is newly recorded from Washington.

Prey records

Agrilus granulatus populi Fisher, 1928: Yakima Co., Yakima, Lewis and Clark Middle School, 46.575°, -120.522°, 12-VII-2012, W. Hellman, 1 specimen. This subspecies is widespread in the western U.S. and Canada and, as its name suggests, utilizes *Populus* spp. (primarily *Populus trichocarpa*) as hosts (Fisher 1928, Barr 1971).

Agrilus politus (Say, 1825): Yakima Co., Yakima, Franklin Park, 46.5953°, -120.5347°, 26-VII-2012, W. Hellman, 2 specimens; 3-VII-2013, C. Looney & A. Pelegrin, 3 specimens; 3-VII-2013, Y. Inguanzo & C. Looney, 1 specimen. Yakima, Lewis and Clark Middle School, 46.575°, -120.522°, 12-VII-2012, W. Hellman, 1 specimen. This is probably the most widespread species of the genus in North America, likely occurring in every state and province (Nelson et al. 2008). Its primary hosts are *Salix* and *Acer* (Nelson et al. 2008). This species is also taken by *C. fumipennis* (Swink et al. 2013).

Chrysobothris nixa Horn, 1886: Yakima Co., Franklin Park, 46.5953°, -120.5347°, 3-VII-2013, C. Looney & A. Pelegrin, 2 specimens; 9-VII-2013, A. Kopit & A. Pelegrin, 1 specimen. Yakima, Lewis and Clark Middle School, 46.575°, -120.522°, 25-VII-2013, Y. Inguanzo & C. Looney, 1 specimen. Occurring from British Columbia to California, east to Montana and Wyoming, the larvae of this species feed on various cupressaceous trees and shrubs (Nelson et al. 2008) and can be a pest in nursery plantings (Burke 1917, Furniss and Carolin 1977).

Chrysobothris quadriimpressa Gory & Laporte, 1837: Walla Walla Co., Walla Walla, Roosevelt Park, 46.064387°, -118.313896°, 19-VII-2012, W. Hellman, 1 specimen. Yakima Co., Yakima, Franklin Park, 46.5953°, -120.5347°, 3-VII-2013, C. Looney & A. Pelegrin, 3 specimens. Formerly listed as a synonym of *C. femorata* (Olivier, 1790) this species has a wide distribution, but mostly in the East. It was first recorded in the Pacific Northwest from southwestern Idaho reared from ornamental black walnut (Westcott 2005), and considered to be introduced, although it was collected from more than one site. A single specimen was later collected in Oregon, near the border with Idaho (Wellso and Manley 2007). Hosts are trees and shrubs in various genera, but the beetle is most often collected on *Quercus* (Wellso and Manley 2007, MacRae and Basham 2013). This species has been recorded as prey of *C. fumipennis* (Hook and Evans 1991, Swink et al. 2013).

Phaenops intrusa (Horn, 1882): Chelan Co., Wenatchee, Eastmont Community Park, 47.417 -120.284, 1-VIII-2012, W. Hellman, 3 specimens. Yakima Co., Yakima, Franklin Park, 46.5953°, -120.5347°, 12-VII-2012, W. Hellman, 7 specimens; 26-VII-2012, W. Hellman, 6 specimens; 2-VIII-2012, W. Hellman, 2 specimens; 3-VII-2013, C. Looney and A. Pelegrin, 7 specimens. Yakima, Lewis and Clark Middle School, 46.5736°, -120.5221°, 6-VII-2013, W. Hellman, 4 specimens; 12-VII-2012 W. Hellman, 9 specimens. This is a widespread western species most commonly taken by beating *Pinus* spp., its most common hosts (Burke 1917 [as *Melanophila*], Nelson et al. 2008), although it has also been reared from *Larix occidentalis* (Nelson and Westcott 1976). Nelson et al. (2008) erroneously listed it from "NB" instead of NE (c.f. Nelson and Westcott 1976).

Discussion

The percentage of search sites occupied by *Cerceris californica* observed in Washington appears to be much lower than for *C. fumipennis* in several eastern states. Nalepa et al. (2012) report that positive ball fields comprised approximately 22% of those surveyed in Maine, Connecticut, and North Carolina, ranging from 9.9% in Maine to 39.3% in Connecticut. Approximately 9% of the fields had large enough colonies (≥15 nests) to monitor, 4.7% in North Carolina and Maine, and 21.8% in Connecticut. This differed sharply from Washington, where in 2012 only about 3.5% of search sites were occupied. More critically, only 1.7% had colonies robust enough to support monitoring (Table 1). Colony size was also smaller than generally reported for *C. fumipennis.*

The largest colony located and monitored in this study included 33 burrows. In contrast, *C. fumipennis* colonies in the northeastern states and provinces could contain hundreds of burrows (Nalepa et al. 2012, Careless et al. 2014). It was expected but still disheartening to find no *C. californica* colonies west of the Cascade Range, where native ash and oak species are found in Washington.

Activity at wasp colonies was rare by August in 2012, suggesting wasps may have been primarily foraging earlier in the season than indicated by museum records and published studies. In 2013, visits to the two largest colonies (in Yakima) began in May. Wasp activity was not observed until mid-June, and appeared to peak in early July; by August almost no wasp activity was observed. This phenology is shorter than that observed for *Cerceris fumipennis*, which displays active enough foraging to enable monitoring through at least mid-August, and sometimes into September (Careless et al. 2014, Hellman and Fierke 2014).

The number of wasps observed and the number of beetles collected per colony were both much smaller than anticipated based on work with *Cerceris fumipennis*. Careless et al. (2014), Hellman and Fierke (2014), and Swink et al. (2013) recovered hundreds of beetles per year, from multiple colonies, compared with the 54 beetles collected in this study. The comparatively abbreviated collecting period in this study may account for part of this difference. Even so, wasp colonies were consistently smaller and less frequent, limiting the potential gains from *C. californica* monitoring. Dropped beetles were seldom found, which presents a challenge to locating colonies since the presence of dropped beetles is a useful indicator (Careless et al. 2014). It also limits the amount of survey data gleaned from each colony, since even damaged beetles collected from the ground can be informative (e.g. Grossbeck 1912, Swink et al. 2013). It is not clear whether the lack of dropped beetles reflects differences in biology or behavior between *Cerceris* congeners, or if it is characteristic of the environment near monitored colonies–low numbers of dropped and captured beetles could simply be a function of low buprestid density near the colonies monitored in this study.

The fairly small pool of prey species observed in this study may similarly derive from relatively poor buprestid habitat located near the study sites. Only five beetle species were retrieved from *Cerceris californica*, although existing literature indicates they prey upon many more species of appropriately sized buprestids given the opportunity. This species-depauperate catch also must be a product of lower abundance and diversity of Buprestidae in WA generally (Barr 1971), particularly compared to the Southwest where most of the *C. californica* prey records originate. For instance, the majority of the recorded prey (60%) of *C. californica* are of *Acmaeodera* spp., which is species-poor in WA and much more diverse in the southwestern USA.

The beetle species captured were not dissimilar in weight and size to *Agrilus planipennis* and *A. auroguttatus*. Since buprestid prey selection appears to be a function of availability and size (Hellman and Fierke 2014), *Cerceris californica* foraging habits observed here and described in other reports indicate that the species has the potential to be an effective monitoring tool if large enough colonies can be located. It is notable

that, although the beetle diversity and numbers retrieved from *Cerceris* were low in each year, the purple prism traps placed in Yakima in 2013–which ran for approximately three months in the same general location–captured no buprestids. In contrast, even the limited *C. californica* monitoring in 2013 resulted in the capture of 18 beetles in four species. Although EAB purple prism traps are hung in ash tree canopies, potentially biasing the available species pool towards ash-feeding buprestids, other species are captured. For example, *Buprestis aurulenta* L., 1767, and *Phaenops drummondi* (Kirby, 1837), were recovered from purple prism traps in western Washington in 2012 and 2013 (J. Cena, personal communication), and detections of other adventive *Agrilus* spp. have come from purple sticky trap captures in other regions (Westcott 2007, Jendek and Grebennikov 2009).

Numerous other wasps and bees were common at baseball diamonds, both occupied and un-occupied by *Cerceris*. Common Hymenoptera genera observed during the survey included other *Cerceris*, *Eucerceris*, *Philanthus*, *Bembix*, *Halictus*, and *Polistes* (Fig. 4). Some of these species are similar in outward appearance to *C. californica*, and confusing them could lead to lost time or other complications. *Polistes dominulus* (Christ), 1791, has somewhat similar coloring and size to *C. californica* and flies relatively slowly. Mistaking these two species could lead to a nasty sting. Discriminating between nests of ground-dwelling species may also be confusing for the novice. *Halictus farinosus* Smith, 1853 (Halictidae) was collected from one of the ballfields with an active *Cerceris* colony. This bee makes nests with a tumulus similar to those of *C. californica*, although the species within can be determined by gently agitating the nest entrance with a stick and eliciting a defensive showing from the occupant. Of the species commonly encountered with *C. californica*, *Philanthus gibbosus* Fabricius, 1775, was the most similar in appearance and behavior. It can be distinguished by its irregular tumulus (Fig. 1) and its bee prey. A colony of *Eucerceris flavocincta* Cresson, 1865, was found at a survey site west of the Cascade Range, where *C. californica* is not known to occur. However, the known range of *E. flavocincta* includes much of *C. californica*'s range (Scullen 1968, Bohart and Grissell 1975). While similar to *C. californica* in color and behavior, *E. flavocinta* preys upon Curculionidae (Bohart and Grissell 1975, Scullen 1968). *Cerceris nigrescens* Smith, 1856 was also found at one site; it too preys upon weevils (Bohart and Grissell 1975).

Following the novel suggestion that beetle-hunting *Cerceris* wasps could be a viable tool in buprestid surveys (Marshall et al. 2005), significant effort has been made to develop and prescribe useful methods of exploiting this phenomenon. Careless et al. (2014) identified three general considerations for evaluating the potential effectiveness of *Cerceris* as a buprestid survey tool: accessibility, productivity, and sustainability. "Accessibility" refers to the temporal, geographic, and behavioral occurrence of the wasp species of interest. *Cerceris californica* nests located in this study were rare, and did not seem to occur in enough sampling locations to be a major source of buprestid survey records. Large colonies were even rarer, limiting effectiveness of this monitoring tool. Colonies of *C. californica* were fairly active during the day, although their seasonal activity may be abbreviated when compared with *C. fumipennis*.

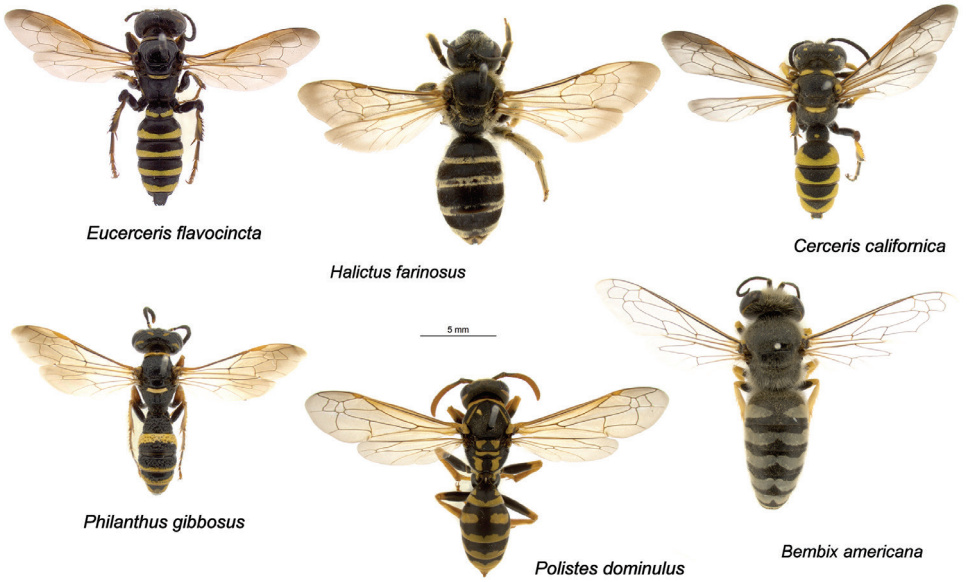

Figure 4. Hymenoptera species commonly found at *Cerceris californica* colonies. The non-*Cerceris* species were observed at the majority of surveyed sites, irrespective of *C. californica*'s presence. *Philanthus gibbosus* was the most notable and similar species likely to be found with *C. californica*.

While far fewer beetles were recovered in this survey than most utilizing *Cerceris fumipennis*, *C. californica* was still relatively "productive", i.e. collected beetles at a rate that equals or exceeds other methods (Careless et al. 2014). We cannot address how effective hand sampling or beating might have been for buprestids, but in 2013, more beetles were recovered from *C. californica* colonies than nearby purple sticky traps. The sticky traps were sited to maximize opportunity to catch EAB – in the upper canopy of ash trees – so this comparison doesn't directly address their *targeted* effectiveness for *Agrilus planipennis*. Even so, the discrepancy in 2013 between beetles captured on traps (0) and those collected in only 19 hours of buprestid monitoring (18) suggests that *C. californica* could play at least a small role in Washington as a supplemental survey technique. Linsley and MacSwain (1956) report hundreds of buprestids recovered from 25 *C. californica* wasps and excavated burrows, indicating that with greater monitoring effort in the right habitat this wasp is productive indeed. No doubt more species and individuals would have been recovered from even the few sites monitored here had there been more collecting time. The last of the effectiveness criteria, "sustainability", concerns the ability of a *Cerceris* species to tolerate repeated interference by humans. This aspect of *C. californica* biology was not directly examined in this study, although Linsley and MacSwain (1956) report that females would continue to embark upon foraging flights, even after having five beetles in a row removed. We can only add the general observation that in this study individual wasps also embarked upon a foraging flight after having a beetle removed.

Ultimately, developing a *Cerceris* monitoring program for exotic buprestids in the western states may be more productive in Oregon or California, where host plant (e.g. *Fraxinus*, *Quercus*) habitat and buprestid-hunting wasp habitat overlap. However, as was the case for Washington before this study, no significant efforts have been made to locate and map colonies of *C. californica* or buprestid-feeding *Cerceris*. This would be a critical first step to monitoring with this species in the western states, particularly since colony frequency and size seem to be the major limiting factors in Washington.

Conclusions

Washington *Cerceris californica* colonies are less common and smaller than *C. fumipennis* colonies in the eastern states. Colonies of *C. californica* appear to be restricted to east of the Cascade Range in Washington state, and were seldom located near EAB trapping sites. *Cerceris californica* captures beetles within the size and weight range of target *Agrilus* spp. Despite low total numbers, *C. californica* wasps were more effective tools for general buprestid sampling in the Yakima area when compared with nearby EAB purple traps, and citizen monitoring may be a useful supplemental monitoring program in select cities in eastern Washington given such effective foraging. The monitoring potential of buprestid-hunting *Cerceris* spp. may be greater in other western states and should be studied.

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