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# Comparison of Trap Collections and Cost of Commercially Available and Homemade Yellowjacket (Hymenoptera: Vespidae) Traps in Lake County, California

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## Abstract

Yellowjackets are notable pests of humans due to their opportunistic foraging behaviors, painful stings, and potential for causing dangerous allergic reactions. Baited traps provide a useful supplement for controlling yellowjackets compared with nest treatments, which are often dangerous, time consuming, costly, and do little to prevent nuisance interactions between humans and foragers. This study compares three homemade yellowjacket traps and three commercially available traps in Lake County, California, to determine efficacy and cost benefit. Traps were set at five sites and randomly rotated between six plots per site and baits were changed every 2 wk per commercial manufacturer recommendations. Cost benefit was determined using material and bait cost, as well as bait change frequency and overall trap efficacy. Yellowjacket count data were analyzed using a hurdle model. Traps compared included the Rescue! Yellowjacket trap, the Rescue! Wasp, Hornet, and Yellowjacket trap, the Victor Yellowjacket trap, a homemade bottle trap, jar trap, and homemade jug trap. The total number of yellowjackets collected was 33,321. The trap that collected the highest number of yellowjackets was the Rescue! Yellowjacket trap (*n* = 19,257) and the trap that collected the fewest yellowjackets was the jar trap (*n* = 65). The Rescue! Yellowjacket trap was the most cost-effective, calculated at approximately $0.40/100 yellowjackets collected. The jar trap was the least cost-effective, calculated at approximately $31.10/100 yellowjackets collected. The Rescue! Yellowjacket trap was overall the most effective and cost-effective trap evaluated for Lake County, California.

**Key words:** control, public health entomology, sampling, social insects, urban and structural entomology

Yellowjackets, especially certain opportunistic foraging species, are notable pests of humans (Akre et al. 1981, Landolt 1998). These insects are attracted to food and beverages during picnics and other outdoor events and can cause a painful sting when provoked that may rarely (1.2–3.5% of people) lead to anaphylaxis, a severe allergic reaction (Palgan et al. 2014). In Lake County, California, the species of greatest concern for public health is *Vespula pensylvanica* (Saussure, Hymenoptera: Vespidae), the western yellowjacket, due to high numbers of workers, nest longevity, and opportunistic foraging habits (Akre et al. 1975, 1976; Akre 1995; Visscher and Vetter 2003). Unlike many other yellowjacket species, *V. pensylvanica* is not strictly predatory and will forage on dead insects and on human foods, including processed meats and sugars (Spurr 1995, Landolt 2003, Cranshaw 2008). Other local vespid species that people may occasionally come into contact with, especially while venturing into rural or natural areas, include *Vespula atropilosa* (Sladen, Hymenoptera: Vespidae), *Vespula acadica* (Sladen, Hymenoptera: Vespidae), *Vespula sulphurea* (Saussure, Hymenoptera: Vespidae), and *Vespula alascensis* (Packard, Hymenoptera: Vespidae) (formerly *Vespula vulgaris*); *Dolichovespula maculata* (Linnaeus, Hymenoptera: Vespidae) (baldfaced hornet); and *Polistes* spp. (paper wasps) (Akre 1981, Carpenter and Glare 2010).

The literature reports that *V. pensylvanica* and *V. atropilosa* queens typically begin foraging between April and early June, though they have occasionally been observed as early as March, while worker activity begins in June and continues through autumn (Akre et al. 1976, Visscher and Vetter 2003). By the end of the summer, nests of *V. pensylvanica* may contain thousands of workers, which suggests that early season control targeting the queen yellowjackets responsible for establishing these large nests has the potential to reduce the number of these pestiferous foraging workers later in the season (Wagner 1961, Akre et al. 1981). Treating nests directly is possible but potentially dangerous and the nests can be difficult to locate (Rust and Su 2012). The use of toxic baits may be effective, but few chemical baits are available (Rust et al. 2017) and are usually combined with meats such as chicken, which are relatively expensive and require replacement every few days (Harris et al. 1991). A simple, safe, and relatively inexpensive alternative or supplement to nest treatments and toxic bait use for controlling nuisance yellowjackets is the use of nontoxic baited traps (Davis et al. 1969, 1972; Landolt 1998; Reierson et al. 2008). Additionally, traps can be effective tools for monitoring yellowjacket activity in an area. A variety of commercial traps are available in addition to a number of do-it-yourself (DIY) style traps that can be simply made using low-cost household materials. In this study, we compare three commercially available traps and three homemade DIY-style traps for efficacy and cost benefit, for monitoring and supplemental control of yellowjackets in Lake County.

## Materials and Methods

In February 2018, five sites around Lake County, California, were chosen and six plots were designated approximately 15–20 m apart within those sites, at which one of each of six different trap types was hung at approximately 1.5 m above the ground. Site 1 was a semiovergrown vacant lot behind the Todd Road facility, owned by the Lake County Vector Control District (Todd), bordered by a chain-link fence, a few trees, and some scrap material. Just outside the fence were two yards and houses with domestic dogs and children, notable ground squirrel (*Otospermophilus* spp.) activity, a small family of mule deer (*Odocoileus hemionus*) as well as mosquito fish (*Gambusia affinis*) breeding ponds. Site 2 was Smiling Dog Ranch and Winery (SD) and consisted of a small vineyard and gated yard containing black walnut (*Juglans hindsii*) and persimmon (*Diospyros* spp.) trees, cultivated peaches, plums, a variety of vegetables and herbs (e.g., squash, tomatoes, sage, garlic, cucumber), gardening supplies, lawn chairs, a couple of sheds, wine-making equipment, and dogs. Neighboring properties had horses and dogs, as well. Site 3 was the Reclamation rice fields in Upper Lake, California (Rec), adjacent to a dirt road and unmanaged vegetation, including Himalayan blackberries (*Rubus armeniacus*) and tules (*Schoenoplectus californicus*). Site 4 was the Lake County Fairgrounds in Lakeport, California (FG); traps were set on a hill covered with un-mowed grasses and old stone foundations, partially surrounded by a chain-link fence, and adjacent to several agricultural buildings and a race track. Site 5 was Steele Wines vineyards (Steele), a winery near a pear orchard and an agricultural supplies store. Plots were designated in a perimeter at each site, with the exception of Rec because the location of the rice prevented hanging traps on one side of the study area.

Three of the traps compared were commercially available traps: The Rescue! Yellowjacket trap (RYJ) baited with approximately 15-ml heptyl butyrate and supplemented with tuna, the Rescue! Wasp, Hornet, and Yellowjacket trap (WHY) baited with 15 ml each of heptyl butyrate and 2-methyl-1-butanol and 26-ml acetic acid (Sterling International, Inc., Spokane, WA), and the Victor Yellowjacket trap (Victor) baited with 13 ml of a protein and carbohydrate concentrated liquid mixture (Victor Poison-Free Yellowjacket Replacement Bait, Safer Brand M385). The other three were homemade do-it-yourself (DIY) style traps: the bottle trap (Bottle), jug trap (Jug), and jar trap (Jar). The bottle trap was assembled by cutting off the top of a 591-ml soda bottle just above the label, inverting it to create a funnel, and securing it with a piece of wire inserted through both the inverted top and the side of the bottle approximately an inch from the top, which was bent into a loop over the top and used to hang the trap (Fig. 1). The bottle trap was then reinforced with duct tape and baited with approximately 300-ml grape juice. The jar trap was created by removing the center from the top of a mason jar and replacing the ring over a square of aluminum foil with an approximately 6.4-mm hole in the center (Fig. 2). The jar was baited with a mixture of 200-ml water, 14-g strawberry jam, 7-g tuna (canned in oil), and approximately 2.5-ml unscented dish soap to prevent escape. The jug trap was created by cutting the top of a plastic gallon jug so that the opening was as wide as the base, but retaining the handle so that wire could be used to tie around it in order to hang the trap. A wooden skewer was pushed through the plastic on both sides, piercing a rolled-up piece of deli ham to act as bait, and the bottom was filled with approximately

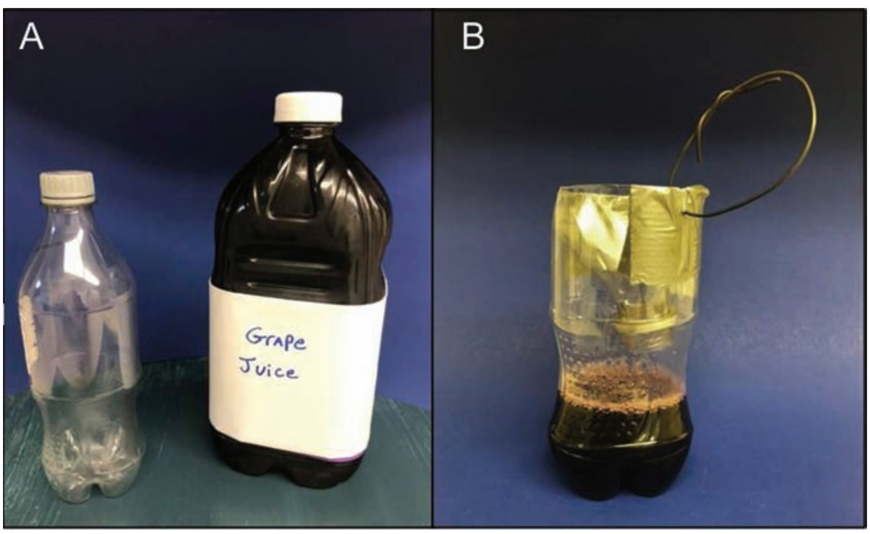


**Fig. 1.** The bottle trap was created using a modified soda bottle and baited with grape juice: (a) 591-ml soda bottles were used to create the bottle traps and jugs containing ~1,920 ml of grape juice were purchased and used to bait between 6 and 7 bottle traps every 2 wk; (b) the finished bottle traps were crafted by removing and inverting the top of the bottle to create a funnel effect, securing the two parts with duct tape, inserting a wire for hanging the trap. Approximately 300 ml of grape juice was added as bait to each bottle trap and this was replaced every 2 wk.

1.8-liter water and 2.5-ml unscented dish soap within ~50 mm below the bait (Fig. 3). Baits used in homemade traps were chosen based on the supplemental attractant recommendations included in the Rescue! trap manufacturer instructions, personal recommendations by local residents, and convenience of use. Tuna and strawberry jam were both recommendations by local residents and were used in combination in the jar trap to provide one of the homemade traps with one protein and carbohydrate mix attractant, similar to the attractant used in the Victor Yellowjacket trap. Traps were randomly rotated between the six plots at each site.

Yellowjackets were removed from the traps once a week and placed in 25–5,000 ml isopropyl alcohol (dependent on number of yellowjackets collected) for preservation in one or two 250-ml plastic cups, labeled with the date, site name, plot number, and trap type. Traps containing live yellowjackets were placed into a cooler with dry ice to anesthetize them for transfer into the cups. Every trap was randomly assigned to a new plot within the site and rotated. Trap baits were replaced every 2 wk, per commercial trap manufacturer recommendations, including homemade traps for consistency.

Data were analyzed in R statistical software (R Core Team 2018) using the pscl package (Zeileis et al. 2008). The outcome of number of yellowjackets caught were treated as count data. Potential predictors included date as a continuous variable, worker versus queen as a binomial variable, and trap type, site, and yellowjacket species

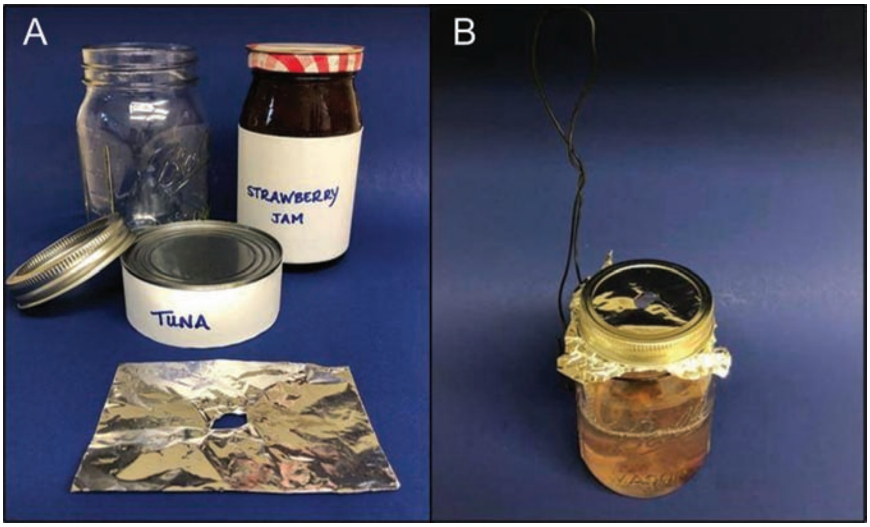


**Fig. 2.** The jar trap was created using a recycled mason jar and baited with a mix of tuna and strawberry jam in water: (a) the middle section of the mason jar lid was replaced with a square of aluminum foil with a 6.4-mm opening cut into the center; tuna stored in oil and strawberry jam were taken from 54-g cans and 510-g jars, respectively, to be used as bait; (b) the finished jar trap contained approximately 7 g of tuna and 14 g of strawberry jam stirred into 200 ml of water and 2.5-ml unscented dish soap. The foil was fastened using the original ring portion of the mason jar lid, the opening allowed yellowjackets access to the bait inside and the dish soap prevented escape by reducing the surface tension of the water. A wire was secured immediately beneath the ring and foil lid and used to hang the trap.

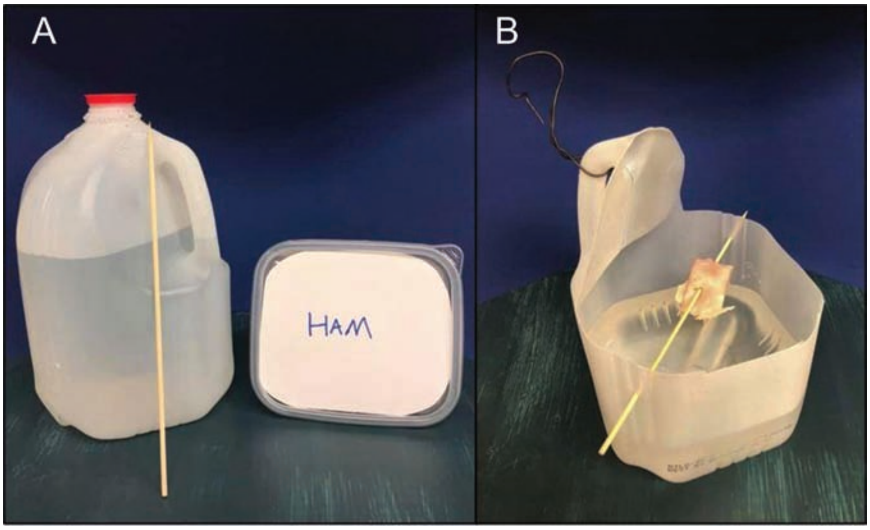


**Fig. 3.** The jug trap was created using a modified water jug and baited with a slice of deli ham on a wooden skewer; (a) jugs containing 3.79 liter of distilled water were emptied and used as the base for the jug traps, wooden cooking skewers and packages of deli style ham were purchased as bait presentation and bait, respectively; (b) the finished traps were created by removing the top half of the jug with the exception of the portion containing the handle, inserting one wooden skewer into the plastic at approximately an inch from the top of the opening on both sides with a piece of deli ham pierced in the center. Approximately 1.8 liter of distilled water and 2.5 ml of unscented dish soap were added, so the bait was suspended 50 mm above the surface.

as categorical variables. Data were analyzed using hurdle models, which are used for count data that has excess zeros (>90% of observations) and is overdispersed (variance is greater than the mean) (Ryan et al. 2017). A hurdle model consists of two parts: 1) a binomial regression to determine the probability that yellowjackets were captured at all and 2) a negative binomial regression to estimate the mean number of yellowjackets caught. Categorical variables were set so that the reference level for each variable was the factor with the lowest number of captures. Results for those categorical variables were reported as 1) the increased probability of detecting yellowjackets, as compared with the reference level and 2) the increased number of yellowjackets detected at a site, as compared with the reference level.

## Results

Initial and per-month trap costs were calculated (Table 1). The least expensive homemade yellowjacket trap to operate over the whole season was the Jar trap ($20.22) and the least expensive commercial trap was the RYJ trap ($76.70).

Eight wasp species were collected: five yellowjackets, two paper wasps, and one hornet were captured in the traps, with the first capture occurring on 4 April 2018. Species captured included the baldfaced hornet *D. maculata* ($n$ = 1), the paper wasps *Polistes aurifer* (Saussure, Hymenoptera: Vespidae) ($n$ = 1) and *Polistes dominula* (Christ, Hymenoptera: Vespidae) ($n$ = 12), and the yellowjackets *V. pensylvanica* ($n$ = 32,323) followed by *V. atropilosa* ($n$ = 870), *V. sulphurea* ($n$ = 177), *V. alascensis* ($n$ = 15), and *V. acadica* ($n$ = 13). Both paper wasps and *D. maculata*, were excluded from the data analysis due to low numbers. Trapping began the week of 13 February 2018 and the first yellowjacket queens (*V. pensylvanica*) were captured the week of 4 April 2018 while the first workers were captured the week of 17 May 2018 (Fig. 4). Abundance of *V. pensylvanica* peaked the week of August 24 ($n$ = 4,383), *V. atropilosa* peaked on July 5 ($n$ = 185), and *V. sulphurea* on June 28 ($n$ = 57). Overall, the trap that collected the highest number of yellowjackets was the RYJ trap ($n$ = 19,257) followed by the WHY trap ($n$ = 12,107), the Jug trap ($n$ = 1,334), the Victor trap ($n$ = 363), the Bottle trap ($n$ = 335), and the Jar trap ($n$ = 65) (Fig. 5). The site that yielded the highest number of yellowjackets was Todd ($n$ = 10,724), followed by SD ($n$ = 10,121), Rec ($n$ = 6,508), FG ($n$ = 4,869), and Steele had the fewest yellowjackets ($n$ = 1,176). Finally, there were far fewer queens ($n$ = 77) than workers ($n$ = 33,321) captured.

When the data were analyzed via hurdle model, only date was not a significant predictor of yellowjacket counts. Compared using the hurdle model, the Jar trap was the least likely to capture yellowjackets and captured the fewest on average. The RYJ trap was the most likely of all the traps to successfully capture yellowjackets and captured the highest number, on average. The RYJ trap was 26.33 times more likely to capture yellowjackets than the jar trap, and when yellowjackets were captured, 94.78 times as many yellowjackets were found in the RYJ trap (Table 2).

## Discussion

The most cost-effective trap for collecting yellowjackets in Lake County, California, is the Rescue! Yellowjacket trap, which cost approximately $0.40/100 yellowjackets captured and captured the highest overall number of yellowjackets ($n$ = 19,197) and the least cost-effective was the Jar trap, which cost approximately $31.10/100 yellowjackets captured and captured the fewest yellowjackets overall ($n$ = 65). The Jar and Bottle traps were both

**Table 1.** Cost to the consumer of each yellowjacket trap over the entire season (9.5 mo of trapping), per month, and initially

| Trap | Initial materials | Initial cost (approx.) | Baits | Bait costs (approx.) | Bait purchase frequency | Bait cost/month | Overall cost for the season (cost × 9.5 mo) |
|---|---|---|---|---|---|---|---|
| Rescue YJ | Trap with included baits | $14.00 | Commercial Pack | $4.60 | Monthly | $6.60 | $76.70 |
| | | | Tuna Can | $1.00 | Every 2 wk | | |
| Rescue WHY | Trap with included baits | $14.00 | Commercial Pack | $4.30 | Every 2 wk | $8.60 | $95.70 |
| Victor | Trap with included baits | $9.00 | Commercial Pack | $5.00 | Every 2 wk | $10.00 | $104.00 |
| Bottle | 591-ml plastic soda bottle | $2.00 | Grape Juice | $4.10 | Monthly | $4.10 | $44.45 |
| | Duct tape | $3.50 | | | | | |
| Jug | 3,785-ml plastic milk jug | $1.60 | Deli Ham | $4.00 | Every 2 wk | $8.00 | $82.90 |
| | Wooden skewers (pack) | $3.00 | | | | | |
| | Dish soap | $2.30 | | | | | |
| Jar | Mason jar | $1.50 | Jam jar | $3.40 | Once | $1.36 | $20.22 |
| | Tin foil | $3.50 | Tuna Can | $1.00 | Every 2 wk | | |
| | Dish soap | $2.30 | | | | | |

Cost is broken down by trap material costs, bait costs, and frequency of bait replacements and was determined using prices listed at retailers in Lake County, CA.

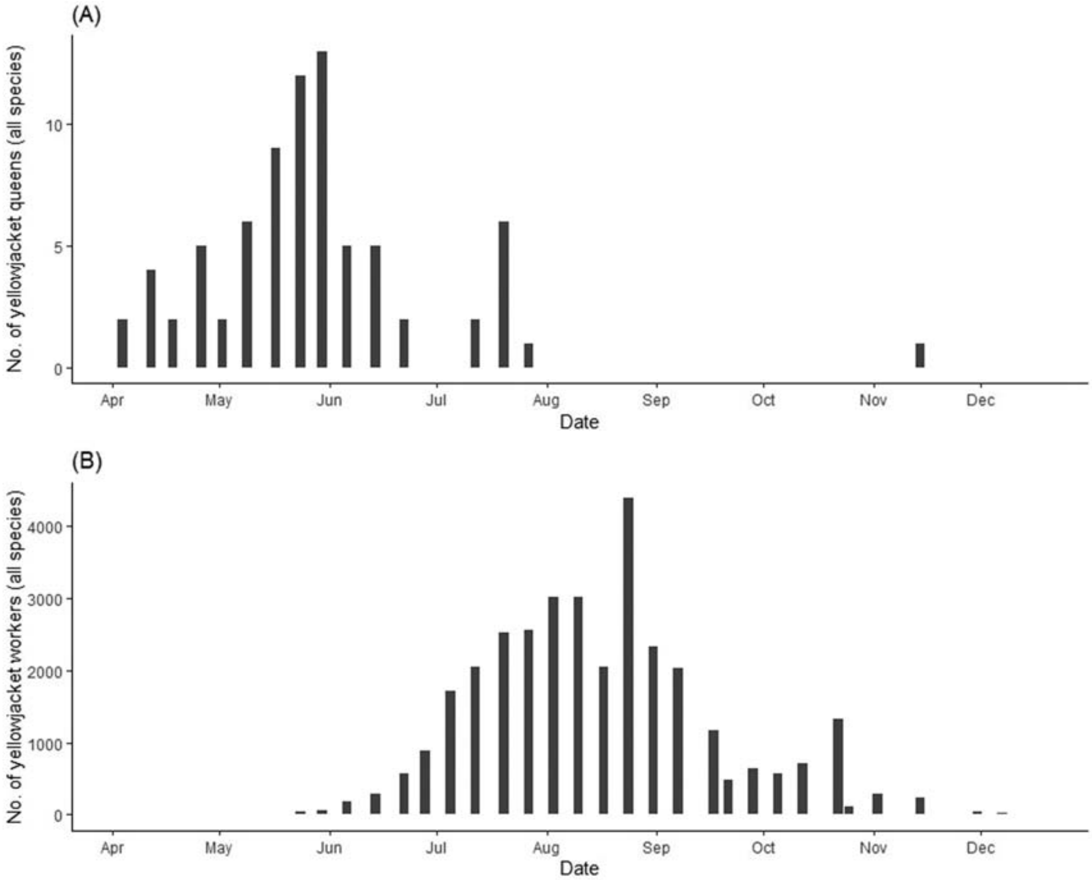


**Fig. 4.** The total number of yellowjackets of all species collected per trapping week from 4 April through 17 December 2018: (a) all yellowjackets collected between 4 April and 9 May 2018 were queens and the majority of yellowjacket queens were collected before August with the exception of a single *V. pensylvanica* queen collected on 14 November; (b) yellowjacket workers were first collected from the traps during the week of 17 May and the final workers were collected on 17 December 2018.

less costly overall, than the RYJ trap, but were significantly less likely to capture yellowjackets. The Victor, WHY, and Jug traps were each more expensive overall and less effective than the RYJ trap, suggesting that the RYJ trap most frequently captures the greatest quantity of yellowjackets in Lake County. Additionally, the RYJ trap was the only trap tested without a liquid element, reducing the need for frequent refilling due to evaporation in the dry heat of northern California summers.

While it is possible to directly treat yellowjacket nests with chemical insecticides, mosquito and vector control districts are often limited to treating only subterranean nests and this does not guarantee control of foragers throughout the season. Direct treatment also creates potentially dangerous situations for pest control operators, as well as individuals treating on their own and, because professionals require the use of a safety suit, this can be quite uncomfortable in the summer and put workers at risk for heat illnesses. Established yellowjacket nests also pose a greater threat to citizens by increasing the number of foraging workers in an area and creating the risk of accidental contact with nests and nest-protective workers.

Although worker foraging activity does not peak until midsummer, early spring trapping captures foraging queens. Each *V. pensylvanica* nest may potentially house thousands of workers (Akre et al. 1981) and early season queen control may reduce numbers of pestiferous foragers later in the season (Wagner 1961). More recent literature suggests that early trapping, specifically, of queens does not reduce overall numbers of foraging workers but trapping throughout the season does reduce interactions between yellowjackets and people (Reierson et al. 2008). Early season trapping of queens may be used as a monitoring tool for residents and pest control operators. Yellowjacket queens were first captured in April during this study, suggesting that traps should be set beginning in March to ensure first collections of the season.

The RYJ trap is baited with heptyl-butyrate, well known as an effective attractant for trapping yellowjackets (Landolt 1998) and can be supplemented with additional bait, if desired. Setting yellowjacket traps in a perimeter to reduce forager activity in an area has been shown to be an effective strategy (Reierson et al. 2008, Rust and Su 2012). Implementing a similar strategy, the use of RYJ traps by residents provides an easy-to-use, cost-effective tool for monitoring and control of the most abundant yellowjacket species in Lake County and reducing human interactions with the nuisance species, *V. pensylvanica*.

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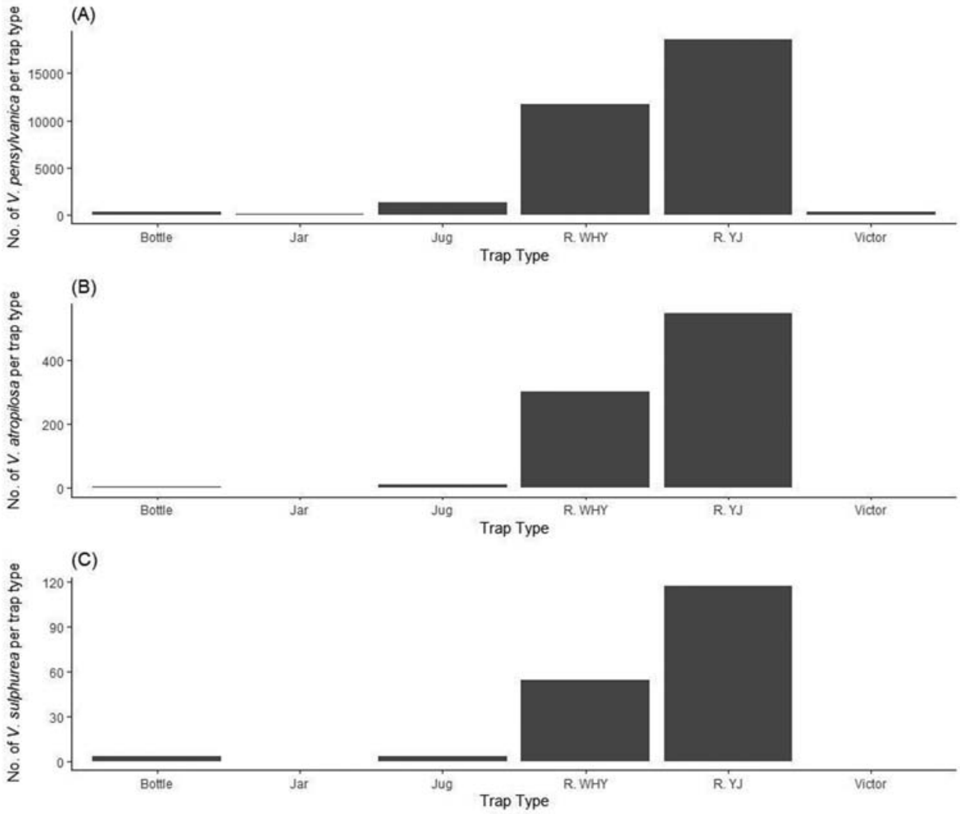


**Fig. 5.** The most abundant yellowjacket species collected in Lake County, California, were *V. pensylvanica*, *V. atropilosa*, and *V. sulphurea*: (a) the RYJ trap collected the highest number of *V. pensylvanica*, followed by the RWHY trap, the Jug trap, the Victor trap, the Bottle trap, and the Jar trap; (b) the RYJ trap collected the highest number of *V. atropilosa*, followed by the RWHY trap, and the Jug trap; and (c) the RYJ trap also caught the highest number of *V. sulphurea*, followed by the RWHY trap, and the Bottle and Jug traps.

**Table 2.** Mean odds of catching yellowjackets and rates of yellowjackets caught (±SE) for four predictor variables calculated using the hurdle model

| Predictor | Odds of catching Yellowjackets ± SE (*P*-value) | Mean number of Yellowjackets caught ± SE (*P*-value) |
|---|---|---|
| Site (reference Steele Winery) | | |
| Todd Road | 3.74 ± 1.20 (*P* < 0.01) | 8.27 ± 1.28 (*P* < 0.01) |
| Fairgrounds | 3.28 ± 1.20 (*P* < 0.01) | 3.59 ± 1.29 (*P* < 0.01) |
| Reclamation | 2.08 ± 1.21 (*P* < 0.01) | 5.51 ± 1.31 (*P* < 0.01) |
| Smiling Dog Ranch | 2.78 ± 1.20 (*P* < 0.01) | 2.72 ± 1.28 (*P* < 0.01) |
| Trap type (reference Jar Trap) | | |
| Rescue! Yellowjacket Trap | 26.33 ± 1.31 (*P* < 0.01) | 94.78 ± 1.51 (*P* < 0.01) |
| Rescue! Wasp Hornet Yellowjacket Trap | 24.86 ± 1.34 (*P* < 0.01) | 53.42 ± 1.55 (*P* < 0.01) |
| Victor Yellowjacket Trap | 2.71 ± 1.32 (*P* < 0.01) | 3.23 ± 1.55 (*P* = 0.01) |
| Bottle Trap | 3.45 ± 1.31 (*P* < 0.01) | 2.24 ± 1.51 (*P* = 0.06) |
| Jug Trap | 5.49 ± 1.34 (*P* < 0.01) | 10.30 ± 1.56 (*P* < 0.01) |
| Species (reference *Vespula acadica*) | | |
| *Vespula atropilosa* | 16.18 ± 1.40 (*P* < 0.01) | 6.17 ± 2.25 (*P* = 0.03) |
| *Vespula pensylvanica* | 102.98 ± 1.39 (*P* < 0.01) | 156.22 ± 2.24 (*P* < 0.01) |
| *Vespula sulphurea* | 4.84 ± 1.43 (*P* < 0.01) | 3.43 ± 2.31 (*P* = 0.14) |
| *Vespula alascensis* | 0.70 ± 1.64 (*P* = 0.47) | 4.84 ± 2.90 (*P* = 0.14) |
| Worker versus Queen | 24.10 ± 1.18 (*P* < 0.01) | 17.00 ± 1.42 (*P* < 0.01) |

Means presented are the odds ratio (odds of catching yellowjackets) for the binomial regression and the rate ratio (mean number of yellowjackets caught) for the negative binomial, which model the likelihood of yellowjackets being present and the presence of yellowjackets, respectively.

Ranch for allowing us to set traps on their property; Steve Tylicki of Steele Wines for allowing us to set traps around the vineyard; Sandi Courcier, Bradley Hayes, Porter Anderson, Terry Sanderson, and Samantha Jo Brassfield at the Lake County Vector Control District staff for their assistance throughout this project; and a special thank you to Mary E. Danforth for assistance with statistical analysis.

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