forests

MDPI

Article

Detection of Emerald Ash Borer (Coleoptera: Buprestidae) in Ash (*Fraxinus* spp.) Crowns in the Southern United States: Comparing Panel Trap Color, Placement, and Lure

Benjamin Walters [1], Mohammad Bataineh [2,*], Stephen Clarke [3], Wood Johnson [4] and William Bruce [4]

1 College of Forestry, Agriculture, and Natural Resources, University of Arkansas at Monticello, Monticello, AR 71656, USA
2 Southern Research Station, USDA Forest Service, 2500 Shreveport Hwy, Pineville, LA 71360, USA
3 Forest Health Protection, USDA Forest Service, 2221 N. Raguet St., Lufkin, TX 75904, USA
4 Forest Health Protection, USDA Forest Service, 2500 Shreveport Hwy, Pineville, LA 71360, USA; crawford.johnson@usda.gov (W.J.); william.bruce@usda.gov (W.B.)
* Correspondence: mohammad.bataineh@usda.gov

Abstract: The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, is an invasive forest pest that is causing a rapid decline in ash (*Fraxinus* spp.). As EABs spread across North America to 35 U.S. states and 5 Canadian provinces, detection of the pest has proven difficult, especially at low population density sites. Panel traps have been commonly used in detection and monitoring of EAB populations. Over two sampling periods from 2016 through 2019, adult catches and detection rates were compared among four combinations of panel trap color, lure, and crown placement in southern Arkansas, northern Louisiana, and eastern Texas. The four combinations were as follows: (1) dark purple baited with (Z)-3-hexenol alone in the mid–upper crown; (2) light green with (Z)-3-hexenol plus (3Z)-lactone in the mid–upper crown; (3) dark purple with (Z)-3-hexenol in the lower crown; and (4) dark purple with (Z)-3-hexenol plus (3Z)-lactone in the lower crown. Mid–upper tree crown placement, ~13 m, of panel traps were more effective for EAB detection and adult capture, especially of males. The sex pheromone (3Z)-lactone deterred females but attracted males, while (Z)-3-hexenol attracted females. The green panel trap with both lures and mid–upper crown placement did not drastically increase male catches, contrary to previous studies at low EAB densities. The use of (3Z)-lactone on dark purple traps at low crown placements, such as those used in the National Survey Program, is not recommended for EAB detection due to its repellent effect on EAB females.

Keywords: emerald ash borer monitoring; invasive insects; (3Z)-hexenol; (3Z)-lactone

Academic Editor: Sergio Angeli

Received: 5 November 2024
Revised: 24 December 2024
Accepted: 28 December 2024
Published: 31 December 2024

Citation: Walters, B.; Bataineh, M.; Clarke, S.; Johnson, W.; Bruce, W. Detection of Emerald Ash Borer (Coleoptera: Buprestidae) in Ash (*Fraxinus* spp.) Crowns in the Southern United States: Comparing Panel Trap Color, Placement, and Lure. *Forests* **2025**, *16*, 54. https://doi.org/10.3390/f16010054

1. Introduction

The emerald ash borer (*Agrilus planipennis* Fairmaire; EAB) is an invasive forest insect that threatens all ash (*Fraxinus* spp. L.) tree species. Since it was first identified in 2002, EAB has expanded its range to 35 U.S. states and 5 Canadian provinces [1]. The expansion of EAB into the southern United States represents a turning point in the insect's biology, with speculations regarding population growth and demographics. Moreover, the ash hosts in these southern states are sparse and are mainly distributed along major streams and rivers, in contrast to the abundant and ubiquitous ash distribution in the northern invasion range, thus influencing EAB's short- and long-distance dispersal [2]. As phloem and cambium feeders, EAB larvae can kill ash trees from within three to five years after establishment [3].

EAB Adults respond to visual cues and are attracted to green and purple hues as well as host volatiles and contact sex pheromones [4,5]. Female EABs produce a short-range pheromone (<5 cm; (3Z)-lactone); however, no long-range pheromones have been identified [6–11]. Visual symptoms of infestation include D-shaped exit holes on the trunk, larval galleries under the bark, epicormic branching, woodpecker feeding, bark splits, and general canopy decline, and are not noticeable until the EAB population is well established [12].

The traps most used for EAB detection and monitoring were the Lindgren multifunnel trap and the corrugated plastic three-panel, or prism, trap. Multifunnel traps have a long history of use in bark beetle (scolytid) trapping [13], whereas the use of corrugated plastic panel adhesive-coated prism traps in an operational detection program is more recent and specific to EAB [14,15]. The three-sided sticky panel traps represent an improvement over early designs that included single panel, box, and cross-vane traps [15,16]. The Lindgren traps consist of collapsible funnels linked together vertically to provide a tree-like silhouette. Although Lindgren traps are reusable and eliminate the need for adhesive coating [17], their use in EAB field surveys is limited due to their bulky size (12–16 funnels), need for a slippery coating (e.g., Fluon), and relatively high maintenance [18].

Green and purple color traps have been demonstrated to be highly attractive to EABs. Retinal sensitivities of EABs peak in the ultraviolet, violet, blue, and green regions of the electromagnetic spectrum, which highlighted the potential for use of these colors in trap designs [4]. Mated females appear to be more sensitive than males to the red region of the light spectrum, which resulted in the use of purple (red and blue) traps in detection and monitoring surveys [4,17]. In optimizing green and purple panel traps, green wavelengths from 525 to 540 nm and a purple color, with reflectance at 12.5% for the red (670 nm) peak reported to be most attractive to EAB [19]. Purple traps with the 12.5% reflectance were more effective than standard purple plastics produced by Coroplast Inc., Granby, QC, Canada, and used in the annual EAB National Survey Program, conducted by Animal and Plant Health Inspection Service (APHIS) [19]. Unbaited dark green panel traps placed at the midpoint of ash tree crowns caught three times more adults than purple traps [4]. At low EAB population densities, green multifunnel and purple panel traps had a comparable proportion of traps with at least one catch during trapping season (i.e., detection rate), although the green multifunnel traps had higher adult catches than purple ones [17]. This higher adult catch has been attributed to the green color traps' resemblance in reflectance to ash foliage available during the adult flight period [19]. The greater attraction of female EABs to purple traps is attributed to the similarity in reflectance to ash tree bark, in which females oviposit [4,20].

EAB's ability to use host-specific volatiles to locate trees, especially stressed ones, led to the identification of bark sesquiterpenes and leaf volatiles that elicit adult EAB antennal activity [20]. The identified antennally active bark volatiles also have been found in manuka and phoebe oils, which are steam distillates from the manuka tea tree (*Leptospermum scoparium*) and Brazilian walnut tree (*Phoebe porosa*), respectively [8,20]. Phoebe oil contains all six antennally active bark volatiles that were identified in the ash tree host, whereas manuka oil lacks one [8]. The green leaf volatile (Z)-3-hexenol had the highest antennal response by males as compared to other hexyl compounds, whereas females responded similarly to all tested hexyl compounds [21]. Bark sesquiterpenes appear to be more attractive to EAB females, whereas green leaf volatiles appear to have an important role in host and mate finding by EAB males [22]. Both bark and ash leaf volatiles were used in the annual EAB National Survey Program, conducted by Animal and Plant Health Inspection Service (APHIS), since 2008.

Trap placement (i.e., height and location within tree crown and surroundings) mediates EAB responses to both lures and trap type and color. Adult activity appeared higher in the upper crowns of ash trees, mostly in warm and sunny conditions, and more EAB males than females were observed hovering around trees [23]. Open grown, edge trees, and southern aspects also are attractive to EAB adults [24–26]. Consequently, more males are caught in green traps placed in ash tree crowns than those placed near ground-level [22]. When traps were placed at 1.5 m above ground, no significant differences in mean adult catches were detected between green panel traps, which attracted more males, and purple panel traps, which attracted more females [4]. Traps placed at midpoint in ash tree crowns had higher adult catches for green traps, whereas no difference in adult catch counts were detected for traps placed at 1.5 m above ground [19]. Trap placement higher in the canopy appears to increase EAB adult catch and is an important factor in improving the EAB detection rate.

Several studies have compared EAB adult trap catches and detection rates using various lure combinations. Dark green panel traps baited only with the (Z)-3-hexenol had comparable catches to those traps baited with manuka oil plus (Z)-3-hexenol [22]. Adding (Z)-3-hexenol to manuka oil lures increased the count of males caught and adult total count as compared to manuka oil alone [22]. Using an 80:20 mix of manuka and phoebe oils caught more EAB adults than standard manuka oil lures used in the National Survey Program [22]. The attractant effect of (Z)-3-hexenol was dampened in dark green panel traps [22], but enhanced in light green panel traps hung in ash tree crowns [27]. Combining the antennally active short-range sex pheromone (3Z)-lactone with (Z)-3-hexenol resulted in increased capture of EAB males, but slightly lowered female capture when green traps were placed in ash tree crowns [28].

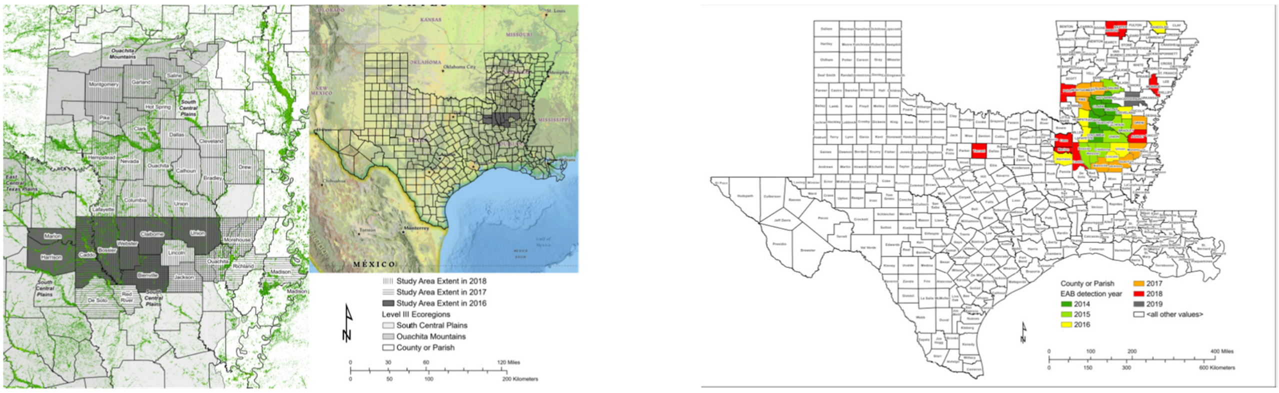
Based on results from trap comparison studies, recommendations for operational detection programs were developed. For example, [4,19,27] suggested that the most effective traps for EAB detection are green panel traps, preferably light green 540 nm, placed at midpoint in ash tree crowns. More recently, (Z)-3-hexenol baited dark green multifunnel and double decker (two panel traps, with dark green upper and light purple lower, attached to a 3 m pole) traps were recommended in a comparison of the most promising operational survey trap types, colors, and lure combinations [29]. Although these comparisons were made in areas of varying infestations levels, they were consistently performed in areas with an abundant and ubiquitous ash tree distribution. Despite evidence for increased colonization likelihood with high host abundance [30] and increased EAB spread when the host is distributed in a linear fashion, such as along roads or waterways [2,31,32], it is still unclear how trap efficacy is influenced in areas with scattered or clustered ash distributions, as is the case in Arkansas, Louisiana, and Texas. Therefore, operational survey trapping recommendations may require revision in areas of sparse and linearly distributed hosts.

The objective of this study was to compare EAB adult catch, detection rate and male/female attraction among four combinations of panel traps within an area of varying infestation levels and sparse ash host distribution, occurring mainly along major rivers and waterways, in Arkansas, Louisiana, and Texas. The four combinations included various, but not the full, factorial levels of lure, color, and tree crown placement, and were specifically as follows: (1) mid–upper crown with (Z)-3-hexenol alone; (2) mid–upper crown with (Z)-3-hexenol plus (3Z)-lactone; (3) lower crown with (Z)-3-hexenol alone; and (4) lower crown with (Z)-3-hexenol plus (3Z)-lactone. For the combination of mid–upper crown with (Z)-3-hexenol plus (3Z)-lactone, a light green panel trap was used as has been previously shown to be superior. A dark purple panel trap was used for the remaining combinations, as was used in the EAB National Survey Program. No unbaited control traps were used in this study, as the usefulness of these traps and lures in EAB detection is already established [4,10,19,22] and this study's focus was on comparing the effectiveness of trap lure, color, and tree crown placement combinations rather than determining their enhanced performance over a control. Lower crown placement corresponded with standard placement for the EAB National Survey Program in the lower crowns of ash trees at no lower than 1.5 m above ground [33], whereas mid–upper placement corresponded to improved green trap efficacy at mid, ~13 m, crown placement [4,19,27].

2. Materials and Methods

2.1. Study Area

The study area encompassed 17 southern Arkansas counties, 14 northern Louisiana parishes, and 2 Texas counties (Figure 1a). The area largely represented EAB-confirmed counties and parishes at the time (Figure 1b). EAB spread within or into these counties and parishes since the first confirmations were reported in 2014, 2015, and 2016 for Arkansas, Louisiana, and Texas, respectively (Figure 1b).



(**a**) (**b**)

Figure 1. Study area extent and emerald ash borer (*Agrilus planipennis*) spread within Arkansas, Louisiana, and Texas. (**a**) Survey region with green ash (*Fraxinus pennsylvanica*) basal area distribution (derived from Individual Species Parameter Maps by the Forest Service, Forest Health Protection, Forest Health Technology Enterprise Team) along major streams and rivers and Ecoregion level III boundaries [34] overlay, and (**b**) Emerald ash borer county- and parish-level spread progression.

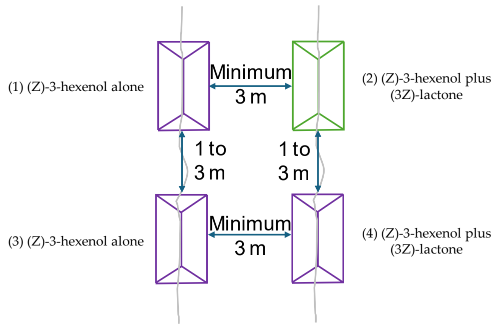
The study area falls largely within the South Central Plains and Ouachita Mountains Ecoregions (Figure 1a). The South-Central Plains Ecoregion is described as dissected rolling plains punctuated with fluvial terraces, bottomlands, and low cuestas. Forests dominate the landscape with loblolly pine (*Pinus taeda* L.), shortleaf pine (*Pinus echinata* Mill.), oaks (*Quercus* spp. L.), gums (*Liquidambar styraciflua* L. and *Nyssa* spp. L.), and hickories (*Carya* spp. Nutt.) as the main species. Ash trees (*Fraxinus* spp.) are sparsely found in upland forests and are mainly distributed along major streams and rivers (Figure 1a). The climate is characterized by warm summers and mild winters. Mean annual precipitation is 135 cm, 70% of which falls in November–May, and the annual frost-free period is 236 days. The Ouachita Mountains ecoregion is characterized by a rugged terrain with east–west-trending ridges. Forests are dominated by loblolly and shortleaf pine on southern and drier aspects and hardwoods, including oak and hickory, on more mesic sites. Ash trees are sparse and linearly distributed along streams and rivers within the study area. The climate is characterized by warm summers and mild winters. Mean annual precipitation is 132 cm, 62% of which falls in November–May, and the annual frost-free period is 196 days.

2.2. Study Design

This study was conducted in two stages, with an initial trapping period in 2016 and 2017 in Louisiana and Texas and a second period in 2018 and 2019 in Louisiana and

Arkansas. For the initial trapping, two combinations of panel trap lure and color were compared in terms of EAB total adult catch and detection rates (i.e., proportion of traps with at least one catch during trapping season). The two combinations consisted of a dark purple standard panel trap baited with (Z)-3-hexenol alone and a light green standard panel trap baited with (Z)-3-hexenol plus (3Z)-lactone (Figure 2). A total of 60 panel traps were deployed in pairs (2 per location), with each pair 1.2–3.0 m apart, representing a complete replicate of the two combinations, for a total of 30 replicates. Each replicate represented a block of relatively uniform EAB population density, host abundance and conditions, and stage of infestation. Trapping locations were selected randomly on roadsides and clearing edges along three transects radiating from a known infested area in Webster Parrish, LA, and extending in a south, east, and west directions (EABs were known to occur in southern AR, eliminating the need for a northern transect). Ten trapping locations 6–16 km apart were selected along each transect. In 2016, both trap lure and color combinations were placed at the same height (±0.3 m) in the mid–upper crown (~13 m) of non-symptomatic ash trees, except for two trees with D-shaped exit holes and/or larval galleries. In 2017, trapping locations were moved outside of the periphery of the known infested area in northern Louisiana. In addition, the purple trap baited with (Z)-3-hexenol was placed in the lower crown, following standard placement in the EAB National Survey Program, and the green trap was placed in the mid–upper crown of non-symptomatic ash trees to test for tree crown placement. The trapping period was March–June of 2016 and 2017.

(a)



(b)

Figure 2. Panel traps used in this study with (**a**) trap design/type and (**b**) setup schematic of the combinations of trap lure, color, and tree crown placement used in 2018 and 2019 with modifications in 2016 and 2017.

For each of 2018 and 2019 trapping, 120 panel traps were deployed in sets of four (i.e., the four combinations of panel trap lure, color, and tree crown placement), each representing a replicate or block of uniform conditions (Figure 2). A total of 30 trapping locations were selected across Arkansas and Louisiana based on known infestation locations, host abundance and availability, and private land access permits. Potential trapping sites were selected using available spatial host and EAB detection datasets, and selected trapping sites were chosen to provide a wide range of infestation and host condition levels within previously EAB-confirmed counties and parishes. The trapping period was March–July of 2018 and 2019. In 2019, traps were redeployed in a similar fashion to provide a replication for the whole study. However, trapping sites were restricted to Clark County, Arkansas, to increase operational feasibility. For 2018 and 2019, trapping in locations with 2014 and 2015 detection dates in Arkansas and Louisiana dictated the use of non-symptomatic and symptomatic trees.

For each trapping site, one suitable ash tree was randomly selected to hang panel traps. Traps were hung from two rope lines separated by a minimum distance of 3 m, and each trap within a line was separated by a minimum of 1–3 m (Figure 2). Minimum distance separating traps and trap lines was, by necessity, shorter than those reported in other studies [14,17,29] due to the sparse distribution of ash trees across various ownerships within the study area. Suitable ash trees were preferably 20 cm or more in diameter at breast height (dbh), dominant or codominant crown class, and located along wooded stand edges or open areas and urban settings. To enhance EAB capture, traps were preferentially placed on the sunny side of trees, south or southwest. The Big Shot Slingshot® (i.e., an oversized slingshot), a throwline and weight, and nylon rope were used to place trap lines [35].

The date and time of measurement, identification number, species, dbh, total height, crown position class (dominant, co-dominant, intermediate, or suppressed), and decline status were recorded. Decline status is a categorical classification of decline progression post EAB-infestation using crown dieback, branch mortality, presence of exit holes, and presence of epicormic branches [3,36]. The relative position of each trapping tree to the edge or interior of a wooded stand was also recorded. Exact trap height was not recorded, but lower crown placement corresponded with standard placement for the EAB National Survey Program in the lower crowns of ash trees at no lower than 1.5 m above ground [33], whereas mid–upper placement corresponded to improved green trap efficacy at mid, ~13 m, crown placement [4,19,27].

For all years, the lures deployed were (Z)-3-hexenol in thin plastic pouches (Item #3136) from Synergy Semiochemicals (Burnaby, British Columbia, Canada) and (3Z)-lactone in rubber-infused septa (Item #P385) from ChemTica Internacional (Heredia, Costa Rica). ChemTica lactone lures are the saturated analog of the macrocyclic lactone (3Z)-dodecen-12olide [37], which can be produced cheaply and have a field and shelf life of 60 days and 2 years, respectively; however, this product is no longer available. Hexenol lures were the same lures purchased and used in the EAB National Survey Programs. Previous trapping effort in Arkansas using (Z)-3-hexenol lures indicated that lures must be replaced after two weeks. Therefore, (Z)-3-hexenol lures were replaced when pouch levels were less than 30% of original to ensure adequate release rates throughout the trapping season, about every two weeks. Due to their long (60 days) field life, (3Z)-lactone lures were not replaced for the duration of the trapping season each year, from March to July.

Traps were revisited every two weeks. For each visit, (Z)-3-hexenol lures were checked and replaced, if necessary, and traps were inspected for EAB catch and proper crown placement. Traps were rotated every other field visit while maintaining the initial randomly assigned tree crown placement to minimize the influence of tree- or site-specific factors on trap performance. Captured EAB adults were transferred to the laboratory, where species identity of adults were confirmed under the microscope and sex of individuals was determined whenever sample integrity allowed. Confirmation of EAB identity relied on three main morphological traits as outlined in Parsons [38]. The three diagnostic traits included the following: (1) coppery-red abdominal dorsal surface; (2) longitudinal mid-dorsal ridge or carina on the last dorsal abdominal segment (i.e., pygidium) projecting beyond the tip of the abdomen as a blunt notched spine; and (3) serrate antennal segments beginning with segment four through segment 11. Determination of an individual sex was based on size and an examination of the texture and pubescence of the ventral plate of the prothorax (i.e., prosternum) and the shape and size of the abdomen, as outlined in Rodriguez-Saona et al. [23].

2.3. Statistical Analysis

Adult catch counts were tabulated by trap and tree and pooled across the catch period for each year. For 2016 and 2017 data, when two trap combinations were used each year, the Wilcoxon signed rank test [39] was used to compare paired trap combinations for each year in terms of the median difference in adult catches (PROC UNIVARIATE, SAS V9.4, 2019 Cary, NC, USA). The mean difference in adult catches among the four trap combinations for each of 2018 and 2019 was tested using the Friedman's test [40], which is a non-parametric analog to an ANOVA based on a completely randomized block design [39]. Trapping locations served as the blocking factor for 2018 and 2019. When the overall Friedman's test indicated significantly different means among the four combinations, the test was repeated for each pair of combinations in lieu of a post hoc means separation test. For each year, male and female counts were separately tested using the same procedures to compare differential sex responses to trap combinations. Adult counts were converted to presence/absence values to calculate McNemar's test statistic for each year [41]. McNemar's test is a non-parametric procedure for paired nominal data, in which the detection rates between each two trap combinations within each year were compared. This test is not affected by the magnitude of EAB collected in a trap, and thus negates the potential of bias from traps in trees, which collected a far greater number of EABs than others. Due to the limited number of discordant pairs [39], exact p values were calculated (PROC FREQ, SAS V9.4, 2019 Cary, NC, USA). To evaluate male/female attraction or preference to lure and tree crown placement within each year, 2×2 contingency tables were constructed and the Fisher Exact Test for count data was used (PROC FREQ, SAS V9.4, 2019 Cary, NC, USA).

3. Results

3.1. Tree Attributes

No tree measurements were recorded for 2016 or 2017; however, all ash trees selected were more than 20 cm in dbh with dominant or codominant crown class. In 2016, only two trees had D-shaped exit holes and/or larval galleries, while the remaining trees were non-symptomatic. All ash trees selected in 2017 were non-symptomatic.

A total of 60 ash trees were measured and used as suitable trapping trees in 2018 and 2019. In 2018, trapping trees were mainly dominant and codominant in the crown position class, with only 20% (six trees) of ash trees in intermediate and suppressed crown positions.

Although no measurements were recorded in 2016 and 2017, in 2018 and 2019, the mean dbh ($\pm$SD) of trapping trees was 29.6 ± 12.6 cm and mean total height ($\pm$SD) was 17.6 ± 7.0 m. Trapping trees in 2018 had a low decline status and ranged from non-symptomatic with healthy appearing crowns (nine trees; 30%) to moderate decline with up to 50% crown dieback (twelve trees; 40%). Remaining ash trees were either standing dead (two trees; 7%) or of severe decline (seven trees; 23%) with more than 50% crown dieback. Most trees (19 trees; 63%) were on the edge of wooded stands or in open areas and urban settings rather than in the interiors of wooded areas.

In 2019, most trapping trees were codominant in crown position class (eighteen trees; 60%), whereas 27% (eight trees) and 10% (three trees) of ash trees were in the intermediate and suppressed crown positions, respectively. Mean dbh of trapping trees was 27.4 ± 10.1 cm and mean total height was 19.6 ± 5.3 m. Trapping trees in 2019 had higher proportions of trees in the high decline classes compared to 2018, partly due to trap deployment in Clark County, Arkansas, only. About half of the trapping trees (14 trees) were non-symptomatic to moderate in decline status. A third of trapping ash trees were standing dead (ten trees), whereas 20% (six trees) were in severe decline. Trapping trees were mainly in the interiors of wooded areas (23 trees; 77%) rather than on the edges of wooded stands or in open areas and urban settings.

3.2. Adult Catch

In 2016, four trap pairs were compromised by theft or damage within the first week. Nine additional trap pairs remained active for only a portion of the trapping period (e.g., missing or vandalized). Consequently, 17 trap pairs remained active throughout the trapping period in 2016. Only ten trap pairs had a catch in 2016, while five trap pairs had a catch in 2017. Twenty and twelve trap sets had a catch in 2018 and 2019, respectively.

A total of 455 beetles were caught in panel traps throughout the trapping period over the four years (Table 1). The highest catches occurred in 2016 (41%) and 2018 (44%) with more extensive trapping in infested areas compared to 2017 (2%) and 2019 (13%). Except for 2017, females made up 51% (234 individuals) and males 46% (211 individuals) of captured beetles over the three remaining years (Table 1). Sex was not determined in 2017. Females made up 47% (89 beetles), 56% (112 beetles), and 57% (33 beetles) of captured beetles in 2016, 2018, and 2019, respectively. Male to female ratios were consistent between years (0.8 for 2018 and 2019, respectively) except for 2016, which had a 1.1 ratio. Adult catches were two to four times higher for the mid–upper crown placement compared to lower crown placement for 2017, 2018, and 2019 (Table 1).

Table 1. Count of emerald ash borer (*Agrilus planipennis*; Coleoptera: Buprestidae) adults caught in panel traps summed across the trapping period from March–July of each of year.

Placement	Trap and Lure	Adult	Male	Female
			20 April–8 June 2016 [1]	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	174	95	79
	Purple; (3Z)-hexenol	14	4	10
			20 April–5 May 2017 [1,2]	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	8	-	-
Lower	Purple; (3Z)-hexenol	2	-	-
			20 April–17 July 2018 [1]	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	60	36	24
	Purple; (3Z)-hexenol	64	18	46
Lower	Purple; (Z)-3-hexenol plus (3Z)-lactone	25	12	13
	Purple; (3Z)-hexenol	50	21	29
			23 April–2 July 2019 [1]	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	19	13	6
	Purple; (3Z)-hexenol	24	6	18
Lower	Purple; (Z)-3-hexenol plus (3Z)-lactone	5	2	3
	Purple; (3Z)-hexenol	10	4	6

[1] Catch dates within a year. [2] Sex was not determined in 2017.

Adult catches did not differ among trap combinations ($p > 0.05$), except for 2016. When both trap systems were placed in the mid–upper crown in 2016, the green panel trap with both lures caught ten more beetles ($p < 0.01$) on average compared to a purple trap baited with (Z)-3-hexenol alone (Table 2). Differences in trap pairs in 2016 were mainly due to the attraction of EAB males to the green panel trap with both lures ($p < 0.01$). Female catches did not differ between trap pairs in 2016 ($p = 0.10$). Mean adult catches did not differ among trap combinations in 2018 ($p = 0.07$), but the mid–upper crown green trap with both lures had three times as many males ($p = 0.03$) compared to lower crown purple trap with both lure types (Table 2). Almost twice as many males were collected using the lower crown trap baited with (Z)-3-hexenol alone than a similar trap with both lures, albeit this was not statistically significant ($p = 0.06$). For females, lower crown traps with (Z)-3-hexenol alone had twice the catch ($p < 0.01$) of traps with the same crown placement but with the addition of (3Z)- lactone (Table 2). Low catches in 2017 and 2019 resulted in no difference among trap combinations for mean adult or either sex catches within each year (each $p > 0.05$). Females were positively attracted to (3Z)-hexenol, whereas males were attracted to both lure types ($p < 0.001$ for 2018 and $p = 0.02$ for 2019). Neither sex was significantly associated with crown placement levels, despite higher counts of males and females in traps placed in the mid–upper tree crown ($p > 0.05$).

Table 2. Mean ± SD of number of emerald ash borer (*Agrilus planipennis*; Coleoptera: Buprestidae) adults caught in panel traps throughout the trapping period, March–July of each year.

Placement	Trap and Lure	Adult	Male	Female
			2016	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	10.2 ± 25.7	5.6 ± 12.8	4.6 ± 13.2
	Purple; (3Z)-hexenol	0.8 ± 1.5	0.2 ± 0.6	0.6 ± 1.4
			2017 [1]	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	0.3 ± 0.8	-	-
Lower	Purple; (3Z)-hexenol	0.1 ± 0.3	-	-
			2018	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	3.0 ± 4.1	1.8 ± 2.2	1.2 ± 2.3
	Purple; (3Z)-hexenol	3.2 ± 6.8	0.9 ± 1.9	2.3 ± 5.0
Lower	Purple; (Z)-3-hexenol plus (3Z)-lactone	1.3 ± 2.5	0.6 ± 1.4	0.7 ± 1.2
	Purple; (3Z)-hexenol	2.5 ± 3.2	1.1 ± 1.6	1.5 ± 1.8
			2019	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	1.6 ± 2.1	1.1 ± 1.6	0.5 ± 0.8
	Purple; (3Z)-hexenol	2.0 ± 2.8	0.5 ± 0.7	1.5 ± 2.3
Lower	Purple; (Z)-3-hexenol plus (3Z)-lactone	0.4 ± 1.2	0.2 ± 0.4	0.3 ± 0.9
	Purple; (3Z)-hexenol	0.8 ± 1.0	0.3 ± 0.5	0.5 ± 0.9

[1] Sex was not determined in 2017.

3.3. Detection Rate

The EAB adult detection rate, which is the percentage of traps with at least one beetle, was relatively low within each year, being 44%, 12%, 36%, and 18% for 2016, 2017, 2018, and 2019, respectively. In 2016, 10 out of 17 traps had at least one catch, whereas 5, 20, and 12 traps had at least one catch for each of the following years, respectively (Table 3).

Table 3. Detection rate and proportion of traps with at least one catch by panel trap lure, color, and placement combination for each year for emerald ash borer (*Agrilus planipennis*; Coleoptera: Buprestidae).

Placement	Trap and Lure	Traps [1]	Traps with Catch	Detection Rate (%)
			2016	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	17	10	59
	Purple; (3Z)-hexenol	17	5	29
			2017 [1]	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	30	5	17
Lower	Purple; (3Z)-hexenol	30	2	7
			2018	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	30	12	40
	Purple; (3Z)-hexenol	30	11	37
Lower	Purple; (Z)-3-hexenol plus (3Z)-lactone	30	6	20
	Purple; (3Z)-hexenol	30	14	47
			2019	
Mid–upper	Green; (Z)-3-hexenol plus (3Z)-lactone	30	7	23
	Purple; (3Z)-hexenol	30	6	20
Lower	Purple; (Z)-3-hexenol plus (3Z)-lactone	30	2	7
	Purple; (3Z)-hexenol	30	6	20

[1] Count of traps at locations with beetle detection.

Although not statistically significant, the adult detection rate for the green trap baited with (Z)-3-hexenol plus (3Z)-lactone was two times higher ($p = 0.06$) than the purple trap baited with only (Z)-3-hexenol when both traps were suspended from the mid–upper crowns in 2016 (Table 3). Adult detection rates for the same trap lure, color, and placement combinations did not significantly differ in 2018 or 2019 ($p > 0.05$). As occurred in 2017, 2018, and 2019, adult detection rates for the mid–upper crown green trap with both lures were comparable ($p > 0.05$) to those of lower crown purple trap with (Z)-3-hexenol alone (Table 3). Adding (3Z)-lactone to the lower crown purple trap baited with (Z)-3-hexenol reduced adult detection rates to a third ($p = 0.06$ in 2019) or half ($p = 0.07$ in 2018) of that for the green trap baited with both lures in the mid–upper crown, albeit not statistically significant. Adding (3Z)-lactone to the lower crown purple trap baited with (Z)-3-hexenol also reduced adult detection rates to a half ($p = 0.02$ in 2018) or two thirds (but $p = 0.22$ in 2019) that of the purple trap baited with only (Z)-3-hexenol in the lower crown. Lower crown placement of a purple trap baited with both lure types resulted in the lowest detection rates in 2018 and 2019 (Table 3). Detection rates were not different between the other pairs of trap combinations for 2018 and 2019 ($p > 0.05$).

4. Discussion

It was expected that fewer adults and lower detections would be recorded in 2017 and 2019. Traps were placed in non-symptomatic ash trees outside of the periphery of the known infested area of northern Louisiana in 2017. Trapping occurred in one of the earliest EAB confirmed counties (Clark County, Arkansas) in 2019, where beetle populations were more likely on the decline following the crest stage of the invasion wave [42]. Although trapping trees were similar in sizes for 2018 and 2019, trees selected during 2019 were in more advanced stages of decline corresponding to the post-invasion dynamics of EABs. Moreover, the higher proportion of selected trees within wooded interiors in 2019 may have further influenced the availability and capture potential of EAB adults.

Mid–upper tree crown, ~13 m, placement of panel traps was more effective for EAB adult detection and capture, especially of males. Placement of traps high in ash tree crowns was previously reported to increase adult capture, especially males [22]. More EAB males than females were observed hovering around trees, and adult activity appears to be higher in the upper crowns of ash trees under warm and sunny conditions [23]. Green panel traps hung at midpoint in ash tree crowns and baited with combined leaf volatile and sex pheromone lures, like that used in this study, were reported to increase the capture of males [22]. However, in this study, purple panel traps placed in mid–upper tree crowns caught similar numbers of beetles during the entire trapping period, indicating that placement in the upper crown is important. Similar capture of beetles in the upper crown with traps of different colors indicates a greater influence of trap placement than color on EAB catch. Tree crown placement of traps also influenced detection rates. Although there was no significant positive association between EAB sex and crown placement, mid–upper crown placement had consistently comparable or higher detection rates compared to other placements.

The lures/color combinations used in this study differentiated between male and female attraction. The green panel trap baited with both lures [(Z)-3-hexenol plus (3Z)-lactone] and placed in the mid–upper crown had consistently higher number of male catches and higher detection rates. The addition of (3Z)-lactone in the mid–upper crown favored capture of EAB males, whereas the use of (Z)-3-hexenol alone in the lower crown favored the capture of females. However, variability in adult catches was high, as was reflected in the high standard deviation values, twice higher than associated means in some cases (Table 2). It is plausible that the shorter, 3 m (10 feet), minimum distance separating traps and trap lines in this study, as compared to those used in previous studies, 10 to 50 m (33 to 164 feet), may have contributed to the high variability in adult catches. Trap proximity may have allowed for potential interference in which insects would be trapped passively by various trap combinations. In previous work, however, distance between traps baited with (Z)-3-hexenol alone did not influence (a slope of zero) adult catches, but traps baited with lactone plus hexenol had higher catches as distance from the hexenol leaf volatile source increased [5]. Such inconsistencies in results from trapping studies have been attributed to the wide variability in stand conditions, relative placement of traps within stands, as well as host abundance, host spatial distribution, and host conditions [6].

The significant association of EAB females to the (Z)-3-hexenol lure was somewhat surprising, as this green leaf volatile typically solicits more responses from EAB males than females [21,22]. The female-produced sex pheromone (3Z)-lactone deterred females, while (Z)-3-hexenol attracted females. This inconsistency with previous reports in effect of (Z)-3-hexenol on EAB females may also be confounded by the choice of trap colors in this study, dark purple, which appears to be more attractive to EAB females along with the difference in host distribution in the southern infestation range of EABs [4,19]. However, the lowest detection rates for purple panel traps baited with (Z)-3-hexenol plus (3Z)-lactone indicated that lactone may be more repellent to females than previously reported [43].

Higher detection rates using light green panel traps hung in upper ash tree crowns was previously reported in [4] and is consistent with the observations reported in this study. Lower crown placement of dark purple panel traps with (Z)-3-hexenol lure alone also had comparable detection rates (Table 3). Upper crown placement of light green panel traps with (Z)-3-hexenol plus (3Z)-lactone lures had consistently high detection rates compared to other placements, which is consistent with previous studies [4]. Lower crown placement of dark purple panel traps with (Z)-3-hexenol lure alone had comparable detection rates (Table 3).

5. Conclusions

In conclusion, the green panel trap with both lures and mid–upper crown placement did not drastically increase male catches, contrary to previous studies at low EAB densities [5,26,27]. Based on the results from this study, the use of (3Z)-lactone on dark purple traps at low crown placements, such as those used in the National Survey Program, is not recommended for EAB detection due to its repellent effect on EAB females. However, the placement of lactone-baited traps in the mid–upper crown appears to increase the catch of EAB males. The standard practice of hanging a purple prism trap baited with (Z)-3-hexenol in the lower crown appears to be adequate in sparse host conditions, as is the case in Arkansas, Louisiana, and Texas, but higher catch rates can be expected if traps are placed higher up in ash tree crowns. Nonetheless, EAB adult catch remain low using standard National Survey Program panel traps and present an obstacle in the early detection and monitoring of EAB populations.

Author Contributions: Conceptualization, M.B. and W.J.; methodology, M.B. and W.J.; validation, M.B., W.J., S.C., B.W. and W.B.; formal analysis, M.B., W.J. and B.W; investigation, B.W., M.B., S.C., W.J. and W.B.; resources, M.B. and W.J.; data curation, M.B. and W.J.; writing—original draft preparation, B.W., M.B., S.C., W.J. and W.B.; writing—review and editing, B.W., M.B., S.C., W.J. and W.B.; visualization, B.W. and M.B.; supervision, M.B. and W.J.; project administration, M.B. and W.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the U.S. Department of Agriculture Forest Service, Forest Health Monitoring, Evaluation Monitoring program, grant no. SO-DG-11083150-014 [M.M.B.], and the APC was funded by the USDA Forest Service Southern Research Station Center for Forest Health and Disturbance—Research Work Unit 4552 Insects, Diseases, and Invasive Plants.

Data Availability Statement: All analyses and data generated during this study are included in this article.

Acknowledgments: The authors thank all individuals that assisted in data collection.

Conflicts of Interest: The authors declare no conflicts of interest. Funding agencies had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Cappaert, D.; McCullough, D.G.; Poland, T.M.; Siegert, N.W. Emerald ash borer in North America: A research and regulatory challenge. *Am. Entomol.* **2005**, *51*, 152–165. [CrossRef]
2. Bataineh, M.M.; Walters, B.L.; Clarke, S.R.; Babst, B.; Ficklin, R. Emerald ash borer infestation in Arkansas: Extent, severity, and progression. In *Forest Health Monitoring: National Status, Trends, and Analysis 2020*; Gen. Tech. Rep. SRS-261; U.S. Department of Agriculture, Forest Service, Southern Research Station: Asheville, NC, USA, 2021; Volume 261, pp. 197–206.
3. Knight, K.S.; Brown, J.P.; Long, R.P. Factors affecting the survival of ash (*Fraxinus* spp.) trees infested by emerald ash borer (*Agrilus planipennis*). *Biol. Invasions* **2013**, *15*, 371–383. [CrossRef]
4. Crook, D.J.; Francese, J.A.; Zylstra, K.E.; Fraser, I.; Sawyer, A.J.; Bartels, D.W.; Lance, D.R.; Mastro, V.C. Laboratory and field response of the emerald ash borer (Coleoptera: Buprestidae), to selected regions of the electromagnetic spectrum. *J. Econ. Entomol.* **2009**, *102*, 2160–2169. [CrossRef] [PubMed]
5. Parker, K.; Ryall, K.; Aukema, B.H.; Silk, P. Early detection of *Agrilus planipennis*: Investigations into the attractive range of the sex pheromone (3Z)-lactone. *Entomol. Exp. Et Appl.* **2020**, *168*, 166–173. [CrossRef]
6. Herms, D.A.; McCullough, D.G. Emerald ash borer invasion of North America: History, biology, ecology, impacts, and management. *Annu. Rev. Entomol.* **2014**, *59*, 13–30. [CrossRef] [PubMed]
7. Pureswaran, D.S.; Poland, T.M. The role of olfactory cues in short-range mate finding by the emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae). *J. Insect Behav.* **2009**, *22*, 205–216. [CrossRef]
8. Crook, D.J.; Khrimian, A.; Francese, J.A.; Fraser, I.; Poland, T.M.; Sawyer, A.J.; Mastro, V.C. Development of a host-based semiochemical lure for trapping emerald ash borer *Agrilus planipennis* (Coleoptera: Buprestidae). *Environ. Entomol.* **2008**, *37*, 356–365. [CrossRef] [PubMed]
9. Lelito, J.P.; Böröczky, K.; Jones, T.H.; Fraser, I.; Mastro, V.C.; Tumlinson, J.H.; Baker, T.C. Behavioral evidence for a contact sex pheromone component of the emerald ash borer, *Agrilus planipennis* Fairmaire. *J. Chem. Ecol.* **2009**, *35*, 104–110. [CrossRef] [PubMed]
10. Silk, P.J.; Ryall, K.; Barry Lyons, D.; Sweeney, J.; Wu, J. A contact sex pheromone component of the emerald ash borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae). *Naturwissenschaften* **2009**, *96*, 601–608. [CrossRef]
11. Bartelt, R.J.; Cossé, A.A.; Zilkowski, B.W.; Fraser, I. Antennally active macrolide from the emerald ash borer *Agrilus planipennis* emitted predominantly by females. *J. Chem. Ecol.* **2007**, *33*, 1299–1302. [CrossRef] [PubMed]
12. Marshall, J.; Storer, A.; Fraser, I.; Mastro, V. Efficacy of trap and lure types for detection of *Agrilus planipennis* (Col., Buprestidae) at low density. *J. Appl. Entomol.* **2010**, *134*, 296–302. [CrossRef]
13. Lindgren, B. A multiple funnel trap for scolytid beetles (Coleoptera). *Can. Entomol.* **1983**, *115*, 299–302. [CrossRef]
14. Francese, J.A.; Oliver, J.B.; Fraser, I.; Lance, D.R.; Youssef, N.; Sawyer, A.J.; Mastro, V.C. Influence of trap placement and design on capture of the emerald ash borer (Coleoptera: Buprestidae). *J. Econ. Entomol.* **2008**, *101*, 1831–1837. [CrossRef]
15. Francese, J.A.; Oliver, J.B.; Fraser, I.; Youssef, N.; Lance, D.R.; Crook, D.J.; Mastro, V.C. Effects of trap design and placement on capture of emerald ash borer, *Agrilus planipennis*. *Gen. Tech. Rep. NRS-P* **2007**, *2007*, 41.
16. Oliver, J.; Fare, D.; Youssef, N.; Klingeman, W. Collection of adult flatheaded borers using multicolored traps. In Proceedings of the Southern Nursery Association Research Conference, Atlanta, Georgia, 11–12 August 2004; pp. 193–199.
17. Crook, D.J.; Francese, J.A.; Rietz, M.L.; Lance, D.R.; Hull-Sanders, H.M.; Mastro, V.C.; Silk, P.J.; Ryall, K.L. Improving detection tools for emerald ash borer (Coleoptera: Buprestidae): Comparison of multifunnel traps, prism traps, and lure types at varying population densities. *J. Econ. Entomol.* **2014**, *107*, 1496–1501. [CrossRef] [PubMed]
18. Francese, J.A.; Rietz, M.L.; Mastro, V.C. Optimization of multifunnel traps for emerald ash borer (Coleoptera: Buprestidae): Influence of size, trap coating, and color. *J. Econ. Entomol.* **2013**, *106*, 2415–2423. [CrossRef]
19. Francese, J.A.; Crook, D.J.; Fraser, I.; Lance, D.R.; Sawyer, A.J.; Mastro, V.C. Optimization of trap color for emerald ash borer (Coleoptera: Buprestidae). *J. Econ. Entomol.* **2010**, *103*, 1235–1241. [CrossRef] [PubMed]
20. Crook, D.J.; Mastro, V.C. Chemical ecology of the emerald ash borer *Agrilus planipennis*. *J. Chem. Ecol.* **2010**, *36*, 101–112. [CrossRef] [PubMed]
21. de Groot, P.; Grant, G.G.; Poland, T.M.; Scharbach, R.; Buchan, L.; Nott, R.W.; Macdonald, L.; Pitt, D. Electrophysiological response and attraction of emerald ash borer to green leaf volatiles (GLVs) emitted by host foliage. *J. Chem. Ecol.* **2008**, *34*, 1170–1179. [CrossRef] [PubMed]
22. Crook, D.J.; Khrimian, A.; Cossé, A.; Fraser, I.; Mastro, V.C. Influence of trap color and host volatiles on capture of the emerald ash borer (Coleoptera: Buprestidae). *J. Econ. Entomol.* **2012**, *105*, 429–437. [CrossRef]

23. Rodriguez-Soana, C.R.; Miller, J.R.; Poland, T.M.; Kuhn, T.M.; Otis, G.W.; Turk, T.; Ward, D.L. Behaviors of adult *Agrilus planipennis* (Coleoptera: Buprestidae). *Great Lakes Entomol.* **2007**, *40*, 1. [CrossRef]
24. McCullough, D.G.; Poland, T.M.; Anulewicz, A.C.; Cappaert, D. Emerald ash borer (Coleoptera: Buprestidae) attraction to stressed or baited ash trees. *Environ. Entomol.* **2009**, *38*, 1668–1679. [CrossRef] [PubMed]
25. McCullough, D.G.; Poland, T.M.; Cappaert, D. Attraction of the emerald ash borer to ash trees stressed by girdling, herbicide treatment, or wounding. *Can. J. For. Res.* **2009**, *39*, 1331–1345. [CrossRef]
26. Ryall, K.L.; Fidgen, J.G.; Silk, P.J.; Scarr, T.A. Efficacy of the pheromone (3Z)-lactone and the host kairomone (3z)-hexenol at detecting early infestation of the emerald ash borer, *Agrilus planipennis*. *Entomol. Exp. Et Appl.* **2013**, *147*, 126–131. [CrossRef]
27. Grant, G.; Ryall, K.; Lyons, D.; Abou-Zaid, M. Differential response of male and female emerald ash borers (Col., Buprestidae) to (Z)-3-hexenol and manuka oil. *J. Appl. Entomol.* **2010**, *134*, 26–33. [CrossRef]
28. Silk, P.J.; Ryall, K.; Mayo, P.; Lemay, M.A.; Grant, G.; Crook, D.; Cossé, A.; Fraser, I.; Sweeney, J.D.; Lyons, D.B. Evidence for a volatile pheromone in *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) that increases attraction to a host foliar volatile. *Environ. Entomol.* **2011**, *40*, 904–916. [CrossRef] [PubMed]
29. Poland, T.M.; Petrice, T.R.; Ciaramitaro, T.M. Trap designs, colors, and lures for emerald ash borer detection. *Front. For. Glob. Change* **2019**, *2*, 80. [CrossRef]
30. Siegert, N.W.; McCullough, D.; Williams, D.; Fraser, I.; Poland, T.; Pierce, S. Dispersal of *Agrilus planipennis* (Coleoptera: Buprestidae) from discrete epicenters in two outlier sites. *Environ. Entomol.* **2010**, *39*, 253–265. [CrossRef] [PubMed]
31. Mercader, R.J.; Siegert, N.W.; Liebhold, A.M.; McCullough, D.G. Dispersal of the emerald ash borer, *Agrilus planipennis*, in newly-colonized sites. *Agric. For. Entomol.* **2009**, *11*, 421–424. [CrossRef]
32. Siegert, N.W.; Mercader, R.J.; McCullough, D.G. Spread and dispersal of emerald ash borer (Coleoptera: Buprestidae): Estimating the spatial dynamics of a difficult-to-detect invasive forest pest. *Can. Entomol.* **2015**, *147*, 338–348. [CrossRef]
33. Buck, J.H. *Emerald Ash Borer Program Manual, Agrilus planipennis (Fairmaire)*; USDA-APHIS-PPQ Emergency and Domestic Programs Emergency Planning: Riverdale, MD, USA, 2015.
34. Omernik, J.M.; Griffith, G.E. Ecoregions of the Conterminous United States: Evolution of a Hierarchical Spatial Framework. *Environ. Manag.* **2014**, *54*, 1249–1266. [CrossRef]
35. Hughes, C.C.; Johns, R.C.; Sweeney, J.D. A technical guide to installing beetle traps in the upper crown of trees. *J. Acadian Entomol. Soc.* **2014**, *10*, 12–18.
36. Smith, A. Effects of Community Structure on Forest Susceptibility and Response to the Emerald Ash Borer Invasion of the Huron River Watershed in Southeast Michigan. Master's Thesis, The Ohio State University, Columbus, OH, USA, 2006.
37. Ryall, K.L.; Silk, P.J.; Fidgen, J.; Mayo, P.; Lavallée, R.; Guertin, C.; Scarr, T. Effects of pheromone release rate and trap placement on trapping of *Agrilus planipennis* (Coleoptera: Buprestidae) in Canada. *Environ. Entomol.* **2015**, *44*, 734–745. [CrossRef]
38. Parsons, G.L. *Emerald Ash Borer (Agrilus planipennis Fairmaire; Coleoptera: Buprestidae)*; Michigan State University: East Lansing, MI, USA, 2008; p. 56.
39. Zar, J.H. *Biostatistical analysis*; Prentice-Hall, Inc.: Hoboken, NJ, USA, 1999; p. 660.
40. Friedman, M. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. *J. Am. Stat. Assoc.* **1937**, *32*, 675–701. [CrossRef]
41. McNemar, Q. Note on the sampling error of the difference between correlated proportions or percentages. *Psychometrika* **1947**, *12*, 153–157. [CrossRef] [PubMed]
42. Burr, S.J.; McCullough, D.G.; Poland, T.M. Density of emerald ash borer (Coleoptera: Buprestidae) adults and larvae at three stages of the invasion wave. *Environ. Entomol.* **2018**, *47*, 121–132. [CrossRef] [PubMed]
43. Domingue, M.; Lelito, J.; Fraser, I.; Mastro, V.; Tumlinson, J.; Baker, T. Visual and chemical cues affecting the detection rate of the emerald ash borer in sticky traps. *J. Appl. Entomol.* **2013**, *137*, 77–87. [CrossRef]