The Probability of Spotted Lanternfly, Lycorma delicatula (Hemiptera: Fulgoridae), Escape Differs Among Life Stages and Between Two Trapping Techniques Commonly Used By Landowners, Sticky Bands and Duct Tape.

Matthew Desko
West Chester University of Pennsylvania

Carolyne Schiebel
West Chester University of Pennsylvania

Samantha Silverman
West Chester University of Pennsylvania

Jessica Bickel
West Chester University of Pennsylvania

Karen Felton
USDA Forest Service

See next page for additional authors

Cover Page Footnote

The authors would like to thank the numerous landowners who graciously allowed us to collect specimens on their property, photograph their tree traps, and discuss their successes with each type of trap. This project was made possible by USDA Section 7721 of the 2019 Plant Pest and Disease Management and Disaster Prevention Program (6.0519). The authors declare no conflicts of interest.

Authors

Matthew Desko, Carolyne Schiebel, Samantha Silverman, Jessica Bickel, Karen Felton, and Jennifer L. Chandler

The Probability of Spotted Lanternfly, *Lycorma delicatula* (Hemiptera: Fulgoridae), Escape Differs Among Life Stages and Between Two Trapping Techniques Commonly Used by Landowners, Sticky Bands and Duct Tape

Matthew Desko[1,†], Carolyne Schiebel[1,†], Samantha Silverman[1,†], Jessica Bickel[1], Karen Felton[2] and Jennifer L. Chandler[1,*]

[1] West Chester University of Pennsylvania, Department of Biology, 730 South Church Street, West Chester, PA 19383

[2] USDA Forest Service, State and Private Forestry, Eastern Region, 180 Canfield Street, Morgantown, WV 26505

†Equal contribution

* Corresponding author: (e-mail: jchandler@wcupa.edu)

Abstract

The invasive *Lycorma delicatula* (White) was first identified in Pennsylvania, U.S.A. in 2014, and has since increased its range to several Eastern states. *Lycorma delicatula* pose a serious threat to many native species, including hardwoods and grapes, and land owners are continually seeking effective traps to control populations. Both commercially-produced Web-Cote brand sticky bands and less expensive duct tape are often used by land owners to trap *L. delicatula*. However, the probability of escape from these adhesives has not been formally assessed, and almost certainly differs as a function of life stage and type of adhesive used. The purpose of this work was to determine if the effect of adhesive type (Web-Cote sticky bands vs. duct tape) on the probability of escape differs based on life stage. Additionally, we wanted to know how escape probability differs among life stages when individuals were exposed to each adhesive type, separately. In all life stages, the probability of escape from duct tape was greater than from Web-Cote sticky bands, indicating that sticky bands are a more effective tool in *L. delicatula* population control. In trials using only Web-Cote sticky bands, the probability of escape was low in second (21.1%), third (32.6%), and fourth (38.5%) instars relative to adults (84.1%). In trials using only duct tape, the probability of escape remained high among all life stages, with approximately 72% of second instars and 100% of adults escaping. Recent studies indicate that alternate trapping techniques, including circle trunk traps, are even more effective at capturing *L. delicatula* than sticky bands, though they are costlier. We propose a hybrid approach to *L. delicatula* trapping which utilizes relatively inexpensive sticky bands early in the season, and fewer, more effective circle trunk traps later in the season.

Keywords: sticky band, invasive species, *Ailanthus altissima*, pest management

The spotted lanternfly, *Lycorma delicatula* (White), is an invasive planthopper native to China that was first detected in Berks County, PA, U.S.A., in 2014, and whose population sizes increased rapidly thereafter (Barringer et al. 2015, Dara et al. 2015, Parra et al. 2017). *Lycorma delicatula* has now been observed in thirty Pennsylvania counties, twenty-six of which are under quarantine due to infestations (Pennsylvania Department of Agriculture 2020, NYSIPM 2020). As of September 2019, the original 130 km^2 quarantine zone had increased to over 24,000 km^2 in Pennsylvania, Maryland, New Jersey, and Delaware, with an additional quarantine established in Frederick County, Virginia (Urban 2019, NYSIPM 2020). CLIMEX and MAXENT models suggest climate and habitat suitability is high for *L. delicatula* throughout many parts of the United States, as well as into South America (Jung et al. 2017, Wakie et al. 2020), and the spread and establishment of *L. delicatula* populations is expected to continue.

Lycorma delicatula's preferred host species is *Ailanthus altissima* (Mill.) Swingle (tree of heaven), an invasive that is common throughout the eastern United States (Dara et al. 2015). However, *L. delicatula* is not host-specific (as reviewed by Ding et al. 2006), and nymphs have been observed on a variety of species, including grapes, hops, cultivated trees, stone fruits, and native trees, including *Juglans nigra* L. (black walnut), *Asimina triloba* (L.) Dunal (pawpaw), and *Acer sp* (maple), with a preference for *A. altissima* evident in late instars and adults (Lee et al. 2009, Park et al. 2009, Kim et al. 2011, Dara et al. 2015, Cooperband et al. 2018, Francese et al. 2020, N. Ritter 2000, personal communication). Both nymph and adult *L. delicatula* exhibit a cyclic behavior pattern wherein individuals climb upward on a vine or tree, fall or jump off often to avoid an obstacle or threat, and subsequently begin to re-ascend that or another host plant (Kim et al. 2011, Francese et al. 2020). Nymphs and adults feed on the leaves, stems, and branches of host plants by using piercing and sucking mouthparts to extract sugar-containing sap (as reviewed by Ding et al. 2006, Dara et al. 2015). Extensive feeding by large groups of *L. delicatula* can lead to open wounds, and the eventual wilting and death of tree branches (Dara et al. 2015). Additionally, the sticky honeydew excreted by *L. delicatula* during feeding coats lower vegetation and is readily colonized by sooty mold (as reviewed by Ding et al. 2006, Lee et al. 2009). *Lycorma delicatula* pose an ecological threat to forests throughout the eastern United States, and an economic threat to various industries including the production of grapes, hops, stone fruits, and cultivated tree stock (Lee et al. 2009, Dara et al. 2015, as reviewed by Lee et al. 2019). In an effort to prevent damage caused by *L. delicatula*, landowners are constantly in search of methods to eradicate individuals from their property.

Numerous trapping techniques have been tested in the field, including sticky bands, BugBarrier tree bands, circle trunk traps, and flight intercept traps (Francese et al. 2020). Francese et al. (2020) recommend the use of circle trunk traps, produced by modifying pecan weevil trunk traps (Great Lakes IPM, Vestaburg MI). Nevertheless, these commercially-available circle trunk traps are relatively expensive per unit, and may be financially inaccessible for private landowners. Many private landowners utilize cheaper, widely-available alternatives such as commercially-produced sticky bands and duct tape (Fig. 1).

Commercially-produced sticky bands are commonly used to control *L. delicatula*, yet the effectiveness is likely limited, as probability of capture undoubtedly varies based on life stage, with a disproportionate number of earlier instars being captured (Cooperband et al.2019, Francese et al. 2020). Indeed, field observations suggest that later instars and adults often crawl onto and back off of sticky bands with varying degrees of effort (Chandler, personal observation). However, the probability of *L. delicatula* escape from sticky bands has not been formally assessed, and information to this effect is valuable for informing banding protocol. Duct tape was initially suggested as a cheaper alternative to commercially-produced sticky bands, although experts warned that duct tape may be less effective because it loses its adhesive quality more quickly than sticky bands, especially after rain (Swackhamer 2018, Etters and Leach 2019). Indeed, duct tape is often observed wrapped around the trunks of trees in areas with large *L. delicatula* populations. Regardless, experimental trials have not tested the effectiveness of duct tape in capturing *L. delicatula*, and it is possible that many landowners are employing this technique with little-to-no success, especially when combatting late-instar nymphs and adults.

Studies have compared differences in the number of individuals captured using various trapping methods, but differences in catch may be confounded by the level of infestation in given areas and on given trees. Less is known about the probability of an individual escaping from a trap once the trap is encountered. After observing individuals of various life stages interacting with sticky bands in the field, we designed a controlled laboratory experiment to answer some simple, yet relatively unexplored questions: (1) Does the effect of adhesive type on the probability of escape vary based on life stage? We predicted that commercially-produced sticky bands would be more effective than duct tape in all life stages. (2) Does the probability of *L. delicatula* escape vary based on the insect's life stage, regardless of the type of adhesive band used? We predicted that the probability of escape across both adhesive band types would increase as life stage increased. (3) Does the probability of *L. delicatula* escape differ between commercially-produced sticky bands and duct tape, regardless of life stage? We hypothesized that even when brand new, duct tape will be inferior to sticky bands regardless of the insect's life stage. (4) For each of the two types of adhesive bands, separately, does the probability of escape vary among life stages? We predicted that the probability of escape from commercially-produced sticky bands will increase as individuals progress in life stage, but will remain relatively low, whereas the probability of escape from duct tape will remain high regardless of life stage. Tree banding is an easy tool for landowners to use in their fight against *L. delicatula*, however, it is probable that banding is not being done optimally, costing landowners valuable time and money. Our goal is to use novel data to answer the questions above, and to add to the growing knowledge base for best management practices in the control and management of *L. delicatula*.

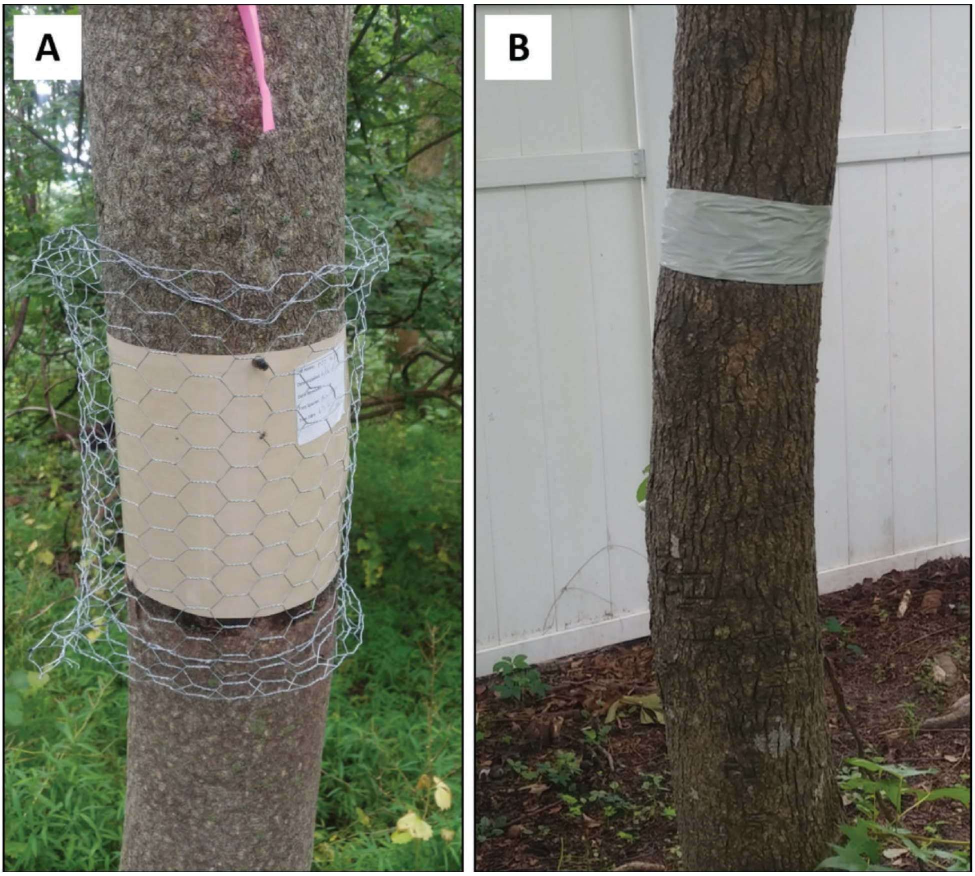

Figure 1. Trees equipped with (a) Web-Cote sticky band wrapped with wire mesh to prevent vertebrate bycatch, and (b) duct tape. Photo credit: Jennifer Chandler

Methods and Materials

In summer 2019, second (n = 41), third (n = 94), and fourth (n = 97) instar, as well as adult (n = 89) *L. delicatula* were captured from forest fragments throughout southeastern Pennsylvania. The opportunistic nature of this study precluded the capture of first instars. Individuals were carefully collected using mesh bags, and were immediately transported to the lab, which was located within the Pennsylvania *L. delicatula* quarantine zone, and held in a mesh enclosure containing fresh *A. altissima* branches for a period not exceeding 24 hours while they awaited testing.

The upper portion of a piece of wood (2.5 cmD × 10.2 cmW × 40.6 cmL), was wrapped completely in an approximately 7.2 cm tall strip of either Web-Cote brand sticky band (Web-Cote Industries, Hamburg, NJ) or Nashua professional grade duct tape (Berry Plastics Corporation, Franklin, MA). Fresh strips of adhesive material were utilized for each trial. Web-Cote sticky bands were utilized in this experiment because this brand was most effective in capturing both nymph and adult *L. delicatula* when compared to generic, clear packing tape and to brown adhesive bands produced by Korea Beneficial Insects Lab Co. (Cooperband et al. 2019). Professional Grade Nashua 398 All-Weather Heavy-Duty HVAC duct tape (11 mil) was used in this experiment, as this tape is an industrial-grade duct tape with a rubber-based adhesive, which forms stronger bonds than polymer-based adhesives. Additionally, the adhesive value (80 oz/in) of Nashua 398 as measured on steel (Berry Plastics Corporation 2011) surpasses the adhesive value of many standard, non-professional grade duct tapes commonly available and utilized by the public.

The adhesive-wrapped wood was oriented vertically within a separate mesh

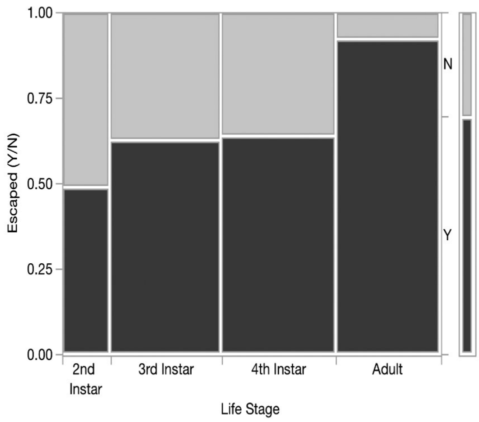

Figure 2. Proportion of individuals in each life stage escaping (dark gray) and being captured (light gray) when pooled across both adhesive band treatments ($\chi^2 = 36.495$, $P < 0.0001$, n = 321).

Table 1. Percentage of *L. delicatula* that escaped from each type of adhesive band within each life stage.

Life Stage	% Escaped (Sticky Band)	% Escaped (Duct Tape)
2nd Instar	21.1	72.7
3rd Instar	32.6	91.7
4th Instar	38.5	93.3
Adult	84.1	100

enclosure, the life stage of a single, randomly-selected *L. delicatula* was recorded, and that individual was carefully released near the base of the piece of wood and allowed to climb vertically to the trap. When necessary, individuals were encouraged to climb upward toward the trap by orienting a small object several inches below the individual, and allowing them to move upward toward the trap and away from the introduced object. Once the individual encountered the adhesive and an escape attempt was initiated, a timer was set for two minutes, within which time the individual could attempt to escape. The two-minute duration was established as the escape threshold based on preliminary observations that lasted for time periods greatly exceeding two minutes. These observations indicated that if the *L. delicatula* failed to escape after two minutes, it was unsuccessful in ever freeing itself. The ability or inability of an individual to escape within the allotted time was recorded. The same process was repeated for each individual collected (n = 321).

Log-likelihood analyses were used to test our hypotheses, with escape (Yes or No) as the nominal response variable, and adhesive type (levels: sticky band and duct tape) and life stage (levels: 2–4 instar and adult) as nominal explanatory variables. A 2 × 4 factorial log-likelihood was performed to evaluate if there is a differential effect of adhesive type and life stage on escape probability (question 1, above), if escape probability varies among life stages, across both adhesive types (main effect 1—question 2, above), and if escape probability differs between adhesive type, averaged across all life stages (main effect 2—question 3, above). To determine how the effectiveness of each band type differs as *L. delicatula* progress to later instars and eventual adults (question 4, above), we split the observations into two groups based on the type of adhesive band used, and we evaluated whether the probability of escape from that band type varies among life stages using log-likelihood. All analyses were performed using JMP Statistical Discovery software (JMP 2019)

Results

The effect of life stage on escape probability did not depend on the type of adhesive band used (Likelihood Ratio $\chi^2 = 1.7149$, $P = 0.6336$). For each life stage, the proportion of individuals escaping was substantially greater when using duct tape than when using sticky bands (Table 1).

The probability of an individual escaping differed depending on life stage (Fig. 2; Likelihood Ratio $\chi^2 = 36.495$, $P < 0.0001$). The percentage of *L. delicatula* able to escape was lowest in 2nd instars (48.8%), was similar among 3rd (62.8%) and 4th (63.9%) instars, and was greatest among adults (92.1%), when pooled over both band types (Fig. 2). The type of adhesive band used influenced the probability of *L. delicatula* escape (Likelihood Ratio $\chi^2 = 70.544$, $P < 0.0001$), with only 47.2% of individuals ranging from 2nd instar to adults escaping from the sticky bands, and 91.9% escaping from duct tape, (Fig. 3).

To better understand the effectiveness of each of the separate adhesive bands in capturing different life stages, we performed analyses which focused solely on individuals introduced to each of the two band types. The first analysis, which focused only on individuals subjected to sticky band trials, indicated that life stage influences the probability of escaping from sticky bands (Likelihood Ratio $\chi^2 = 37.196$, $P < 0.0001$). The proportion of individuals that escaped from sticky bands increased with life stage progression, with a marked increase in escape observed in adult *L. delicatula* (Fig. 4). A separate analysis which focused only on individuals exposed

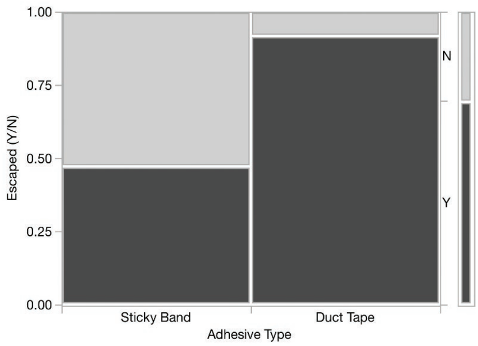

Figure 3. Proportion of individuals escaping (dark gray) and being captured (light gray) on sticky bands (n=161) and duct tape (n= 160) when pooled across all life stages (χ^2 = 70.544, P < 0.0001).

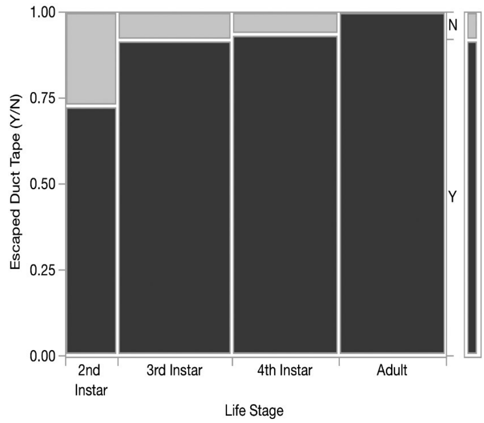

Figure 5. Proportion of individuals in each life stage escaping from duct tape (dark gray) and being captured by duct tape (light gray) (χ^2 = 14.818, P = 0.0020, n = 160).

to duct tape trials also indicated that life stage influences the probability of escaping duct tape (Likelihood Ratio χ^2 = 14.818, P = 0.0020). One-hundred percent of adults escaped from duct tape, and while the probability of escape was somewhat lower in 2nd instars (72.7%), the proportion of individuals that escaped was still high among all life stages (Fig. 5).

Discussion

Sticky bands are a popular, recommended method for reducing populations of the invasive *L. delicatula*. Alternatively, duct tape is suggested as a cheaper, readily available option for private use (Etters and Leach 2019). We tested the effectiveness of both methods to determine which led to a higher probability of *L. delicatula* capture throughout nymphal and adult life stages. The likelihood of *L. delicatula* escape was highest in more advanced life stages regardless of band type, though Web-Cote sticky bands were more effective than duct tape overall. Additionally, duct tape appears wholly ineffective in capturing adult *L. delicatula* (0% captured) whereas sticky bands were somewhat more effective in capturing adults (15.9% captured). Generally, these results suggest that placing Web-Cote sticky bands out when *L. delicatula* are still in early nymphal stages, as opposed to adults, will result in greater capture of early instar *L. delicatula*, will facilitate population reductions, and will consequently reduce the number of individuals that will become breeding adults.

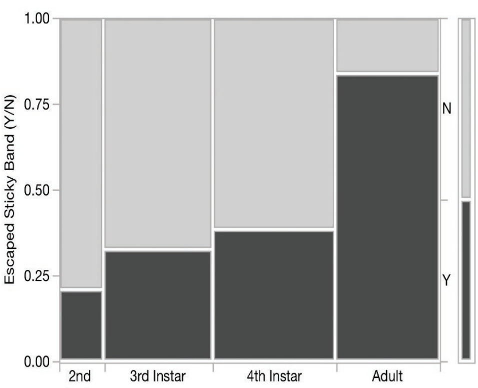

Figure 4. Proportion of individuals in each life stage escaping from sticky bands (dark gray) and being captured by sticky bands (light gray) (χ^2 = 37.196, P < 0.0001, n = 161).

First instars were not utilized due to the opportunistic nature of this experiment. However, based on the results of this experiment we expect that 1st instars would have the lowest probability of escape on both adhesive types. Anecdotal evidence suggests that some proportion of 1st instars are captured by duct tape, but the actual probability of capture is uncertain. As such, it is possible that landowners may have some degree of success capturing 1st instar *L. delicatula* using duct tape if the tape is placed out early to align with the beginning of the *L. delicatula* life cycle, and is replaced often. Additionally, landowners may choose to wrap trees with multiple bands of duct tape to increase the width of the surface on which early instars may be captured. Nevertheless, duct tape appears far less effective than Web-Cote sticky bands, and landowners that use duct

Figure 6. An adult spotted lanternfly (*Lycorma delicatula*) avoids being captured on the adhesive by utilizing the wire mesh that has been placed around a sticky band to prevent vertebrate bycatch. Photo credit: Jennifer Chandler

tape to capture 1st instars will need to switch to alternate methods to effectively capture individuals that are advanced beyond the 1st instar life stage. Only one brand of duct tape was used in this experiment, and as such, we must avoid making sweeping generalizations about the effectiveness of *all* types and brands of duct tape. Even so, the brand chosen was professional grade and had high adhesive value, and while other brands may vary slightly in effectiveness against *L. delicatula*, it is unlikely that the overall results would be significantly altered.

Results obtained from this study were from a controlled laboratory setting, and as such, they may represent "best case scenario" capture rates. Field conditions, including temperature variations, precipitation, and the accumulation of debris on the adhesive surface between band changes, can influence capture rate. Etters and Leach (2019) suggest that duct tape loses much of its adhesive quality when wet, and field observations indicate that the same is true of commercially-produced sticky bands (Chandler, personal observation). Additionally, if a significant amount of debris (leaves, twigs, dead carcasses of captured insects, etc.) accumulates on the adhesive between band changes, *L. delicatula* can use the debris as a "bridge" over the adhesive (Chandler, personal observation). Further, it is highly recommended that wire mesh, such as chicken wire, be placed around sticky bands to prevent bycatch of birds and small mammals (Finlay and Seifrit 2018, Etters and Leach 2019). We often observed *L. delicatula* crawling up the wire mesh that was situated at least 1-inch away from the main stem with only the top and bottom of the mesh in contact with the tree, thus avoiding the adhesive

(Fig. 6; Chandler, personal observation). As such, the probabilities of capture reported in this laboratory study are likely higher than can be expected when bands are placed in field conditions.

Recently, both the effectiveness of sticky bands modified with attractant lures as well as the effectiveness of alternate trapping methods have been assessed (Cooperband et al. 2019, Francese et al. 2020). Cooperband et al. (2019) tested for attraction of *L. delicatula* to several volatile compounds and found that methyl salicylate (wintergreen oil) attracted all life stages, and further determined that sticky bands baited with methyl salicylate resulted in up to a four-fold increase in capture when compared to sticky bands that lacked the volatile lure. A separate study compared the number of *L. delicatula* captured among several types of physical traps, including Web-Cote sticky bands, BugBarrier Tree Bands (Environmetrics Systems USA, Inc., Victor, NY), and circle trunk traps (modified pecan weevil traps, Great Lakes IPM, Vestaburg, MI), among others (Francese et al. 2020). Francese et al. (2020) did not assess the probability of escape once the trap was encountered, as did the current study, but rather investigated the mean number of individuals captured on trees that are equipped with different types of traps. Francese et al. (2020) compared standard Web-Cote sticky bands and BugBarrier bands, a trap design in which the adhesive surface faces inward toward the tree with a gap between the band and tree that provides access to climbing insects. Their results indicated that the number of early stage *L. delicatula* captured did not differ among the two traps, but that BugBarrier bands trapped more late-instar and adult individuals (Francese et al. 2020). Further, while there was no difference in the number of early stage *L. delicatula* between BugBarrier bands and circle trunk traps, circle trunk traps captured more 4th instars and adults (Francese et al. 2020).

When deciding which trapping method to use, landowners must consider the quantity of trees on which they need to place traps as well as the monetary and time investments that go into each type of trap. It seems that Web-Cote sticky bands wrapped with wire mesh to avoid bycatch are still a viable option in efforts to reduce population sizes. However, perhaps there is a more thoughtful, hybrid approach wherein relatively cheap, easy to use Web-Cote sticky bands baited with methyl salicylate are deployed on a diverse array of species early in the season to effectively capture generalist, early-stage nymphs. Then, as host preference trends toward *A. altissima* later in the season (Kim et al. 2011), landowners may target fewer trees with the costlier traps that are more effective against late-instars and adults, also baited with methyl salicylate. This hybrid approach, or perhaps a similar approach, may be time- and cost-effective for private landowners. Additionally, this approach will maintain expected capture rates over the season, while also substantially reducing the occurrence of problems associated with traditional sticky bands, such as vertebrate bycatch, by simply reducing the amount of time that traditional sticky bands are deployed.

Acknowledgments

The authors would like to thank the numerous landowners who graciously allowed us to collect specimens on their property, photograph their tree traps, and discuss their successes with each type of trap. This project was made possible by USDA Section 7721 of the 2019 Plant Pest and Disease Management and Disaster Prevention Program (6.0519). The authors declare no conflicts of interest.

Literature Cited

Barringer, L.E., L.R. Donovall, S. Spichiger, D. Lynch, and D. Henry. 2015. The First New World Record of *Lycorma delicatula* (Insecta: Hemiptera: Fulgoridae). Entomological News 125(1): 20–23. DOI: 10.3157/021.125.0105

Berry Plastics Corporation. 2011. Nashua Tape Products 398 Professional Grade Duct Tape [Product Specification Sheet]. Franklin, MA: Berry Plastics Corporation. Available from https://www.e-aircraftsupply.com/MSDS/111237Nashua%20398.pdf

Cooperband, M., J. Wickham, N. Derstine, I. Canlas, K. Murman, M. Wallace, S-E. Spichiger, J. Baker, and D. Carrillo. 2018. Spotted lanternfly: Hosts, attractants, and dispersal, pp. 32–34. *In* McManus, K.A. (ed.), 29th USDA Interagency Research Forum on Invasive Species. United States Department of Agriculture, Annapolis, MD. 88pp

Cooperband, M.F., J. Wickham, K. Cleary, S-E. Spichiger, L. Zhang, J. Baker, I. Canlas, N. Derstine, and D. Carrillo. 2019. Discovery of Three Kairomones in Relation to Trap and Lure Development for Spotted Lanternfly (Hemiptera: Fulgoridae). Journal of Economic Entomology 112(2): 671–682. DOI: 10.1093/jee/toy412

Dara, S.K., L. Barringer, and S.P. Arthurs. 2015. *Lycorma delicatula* (Hemiptera: Fulgoridae): A new invasive pest in the United States. Journal of Integrated Pest Management 6(1): 20.

Ding, J., Y. Wu, H. Zheng, W. Fu, R. Reardon, and M. Liu. 2006. Assessing potential biological control of the invasive plant, tree-of-heaven, *Ailanthus altissima*. Biocontrol Science and Technology 15(5/6): 547–566.

Etters, T., and H. Leach. 2019. Using Traps for Spotted Lanternfly Management. Pennsylvania State University, Penn State Extension. Available from: https://extension.psu.edu/using-traps-for-spotted-lanternfly-management (accessed 15 July 2019).

Finlay, E., and D. Seifrit. 2018. Spotted Lanternfly Banding. Pennsylvania State University, Penn State Extension. Available from: https://extension.psu.edu/spotted-lanternfly-banding (accessed 12 January 2020).

Francese, J.A., M.F. Cooperband, K.M. Murman, S.L. Cannon, E.G. Booth, S.M. Devine, and M.S. Wallace. 2020. Developing Traps for the Spotted Lanternfly, *Lycorma delicatula* (Hemiptera: Fulgoridae). Environmental Entomology 49(2): 269–276. DOI: 10.1093/ee/nvz166

JMP®. 2019. Version 15. SAS Institute Inc., Cary, NC.

Jung, J-M., S. Jung, D-H. Byeon, and W.H. Lee. 2017. Model-based prediction of potential distribution of the invasive insect pest, spotted lanternfly *Lycorma delicatula* (Hemiptera: Fulgoridae), by using CLIMEX. Journal of Asia-Pacific Biodiversity 10: 532–538.

Kim, J.G., E-H. Lee, Y-M. Seo, and N-Y. Kim. 2011. Cyclic behavior of *Lycorma delicatula* (Insecta: Hemiptera: Fulgoridae) on host plants. Journal of Insect Behavior 24: 423–435.

Lee, J.E., S.R. Moon, H. G. Ahn, S.R. Cho, C. Yoon, and J.H. Kim. 2009. Feeding behavior of *Lycorma delicatula* (Hemiptera: Fulgoridae) and response on feeding stimulants of some plants. Korean Journal of Applied Entomology 48: 467–477.

Lee, D., Y. Park, and T.C. Leskey. 2019. A review of biology and management of *Lycorma delicatula* (Hemiptera: Fulgoridae), an emerging global invasive species. Journal of Asia-Pacific Entomology 22(2): 589–596.

NYSIPM. 2020. New York State Integrated Pest Management: Spotted Lanternfly. Cornell College of Agriculture and Life Sciences. Available from: http://www.nysipm.cornell.edu/environment/invasive-species-exotic-pests/spotted-lanternfly/ (accessed 1 May 2020).

Park, J.D., M.Y. Kim, S.G. Lee, S.C. Sin, J.H. Kim, and I.K. Park. 2009. Biological characteristics of *Lycorma delicatula* and the control effects of some insecticides. Korean Journal of Applied Entomology 48: 53–57.

Parra, G., H. Moylett, and R. Bulluck. 2017. Technical working group summary report – spotted lanternfly *Lycorma delicatula* (White, 1845), pp. 42. USDA-APHIS-PPQ-CPHST, Raleigh, NC.

Pennsylvania Department of Agriculture. 2020. Quarantine.Available from: http://www.agriculture.pa.gov/Plants_Land_Water/PlantIndustry/Entomology/spotted_lanternfly/quarantine/Pages/default.aspx (accessed 1 May 2020).

Swackhamer, E. 2018. Spotted lanternfly management options: Placing sticky bands on trees. Pennsylvania State University, PennState Extension. Available from: https://www.agriculture.pa.gov/Plants_Land_Water/PlantIndustry/Entomology/spotted_lanternfly/program-information/Documents/Tree%20Banding%20factsheet.pdf (accessed 19 September 2019).

Urban, J.M. 2019. Perspective: Shedding Light on Spotted Lanternfly Impacts in the USA. Pest Management Science 76(1):10–17. Available from: https://doi.org/10.1002/ps.5619

Wakie, T.T., L.G. Neven, W.L. Lee, and Z. Lu. 2020. The establishment risk of *Lycorma delicatula* (Hemiptera: Fulgoridae) in the United States and Globally. Journal of Economic Entomology 113(1): 306–314.