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Line-Trapping of Codling Moth (Lepidoptera: Tortricidae): A Novel Approach to Improving the Precision of Capture Numbers in Traps Monitoring Pest Density

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Abstract

This field study of codling moth, *Cydia pomonella* (L.), response to single versus multiple monitoring traps baited with codlemone demonstrates that precision of a given capture number is alarmingly poor when the population is held constant by releasing moths. Captures as low as zero and as high as 12 males per single trap are to be expected where the catch mode is three. Here, we demonstrate that the frequency of false negatives and overestimated positives for codling moth trapping can be substantially reduced by employing the tactic of line-trapping, where five traps were deployed 4 m apart along a row of apple trees. Codling moth traps spaced closely competed only slightly. Therefore, deploying five traps closely in a line is a sampling technique nearly as good as deploying five traps spaced widely. But line trapping offers a substantial savings in time and therefore cost when servicing aggregated versus distributed traps. As the science of pest management matures by mastering the ability to translate capture numbers into estimates of absolute pest density, it will be important to employ a tactic like line-trapping so as to shrink the troublesome variability associated with capture numbers in single traps that thwarts accurate decisions about if and when to spray. Line-trapping might similarly increase the reliability and utility of density estimates derived from capture numbers in monitoring traps for various pest and beneficial insects.

Key words: sampling, long-line trapping, $\mu5$, economic threshold, absolute pest density

Monitoring traps baited with sex pheromones have been playing a critical role in insect pest management since the 1970s by identifying what pests are present in a crop and when they are active (Witzgall et al. 2010). Moreover, significant advances have recently been made in the development (Miller et al. 2015) and validation (Adams et al. 2017) of methodologies for converting catch numbers in pheromone-baited traps into estimates of absolute pest density, the key parameter required for generating economic thresholds intended to optimize control decisions. It is becoming increasingly clear that insects foraging for pheromone plumes displace via biological random walks (Miller et al. 2015, Adams et al. 2017), and that captures result from stochastic intersections of movers travelling large distances with relatively small plumes from monitoring traps. For example, codling moth, *Cydia pomonella* (L.), males typically displace an estimated total of 3 km while foraging for pheromone along a convoluted path that results in a net displacement rarely >300 m (Adams et al. 2017). By contrast, plume reach for an optimized codling moth monitoring trap has proven to be <5 m (Adams et al. 2017).

Given the stochastic nature of trapping, an important consideration when using catch numbers to guide management decisions will be precision—what is the level of agreement of a particular catch number with itself when repeated measures are taken under identical conditions? Despite heavy use of catch numbers in insect pest management, precision of such numbers has drawn very little attention to date, save for a brief introduction to the topic by Miller et al. (2015).

The following specific example drawn from our recent codling moth trapping research (Adams et al. 2017) illustrates the range of catch numbers possible from a single trap and the risks of using a single datum from one trap as the driver of pest management decisions. Adams et al. (2017) found that the trapping radius for a single codling moth monitoring trap not under mating disruption was ca. 260 m, yielding a sampling area of ca. 21 ha. The mean probability of capture (T_{fer}) of a standard monitoring trap baited for codling moth males was ca. 0.015 across the sampling area, and therefore the mean probability that the males in the sampling area would not be caught was 0.985. As documented by Miller et al. (2015), catch per sampling area equals T_{fer} multiplied by males per trapping area. Knowing the T_{fer} (probability of success) value, it is also possible to calculate the distribution of catch probabilities for a given pest density using the binomial distribution formula:

$$b(x;\ n,\ P) = nC_x * P^x * (1 - P)^{n-x} \tag{1}$$

where b = binomial probability; x = total number of successes; n = number of trials (males per trapping area); P = probability of a success on an individual trial; and $_nC_x$ = the combination of n entities taken x at a time. Figure 1 shows a probability distribution generated using a probability of success of 0.015 with $n = 220$, which equates to ca. 10 codling moth males per ha (4/ac). In this example, the most frequently observed catch value is three codling moths, the recommended threshold for action. This catch of three is realized in only 22% of trials, while a catch of zero is to be expected in ca. 4% of trials, and a catch of six can be expected 3% of the time. Although rare, catches as high as 12 can also occur. However, the preponderance of catches will fall between one and six.

This wide range in codling moth catch outcomes is sobering because it degrades accuracy of decisions on whether or not to spray for this key pest of global apple production. For example, in Michigan apple production, the action threshold for second-generation codling moth is a cumulative catch of three or more males per trap (Gut and Wise 2016). In light of Fig. 1, the current system of interpreting capture numbers from single monitoring traps operating at an actual threshold density of codling moth could result in sprays being applied when they are not needed (ca. 40% probability). But worse from the perspective of grower exposure to crop loss, the probability of false negatives is also substantial (ca. 20%).

That realization led us to seek improvements in monitoring protocols so as to tighten the correlation between catch number and the true probability of damage. One possible tactic might be to raise the codlemone release rate so as to enlarge the reach of the plume emanating from the codling moth trap, thus making it a larger target for intersections with foraging males. However, this approach is refuted

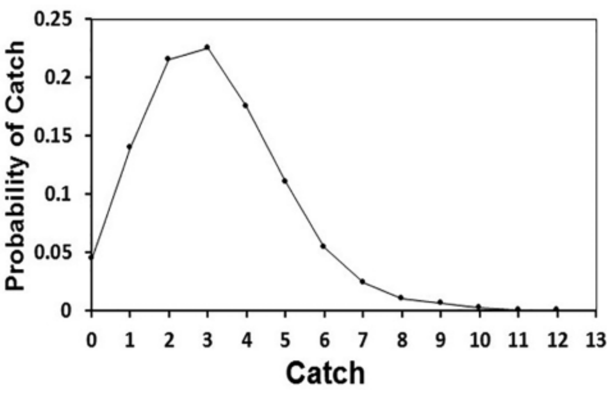

Fig. 1. Probabilities of realizing respective catches from 0 through 12 as ascertained from the binomial distribution formula when $T_{fer} = 0.015$ and codling moth density is 220 per sampling area of a single trap (value selected to produce a catch mode of 3 so as to match the Generation 2 action threshold for spraying codling moth in Michigan). A virtually identical frequency histogram was produced using Weston MultiMover software (Weston 1986, Miller et al. 2015) and randomly seeding 220 movers into a discoid trapping area having radius 260 pixels and containing a central trap with a reach of 2 × 2 pixels. When the number of steps taken was 3,000 and the circular standard deviation of headings for new steps was 30°, T_{fer} was ca. 0.015. Thus, the probability distribution in this figure was arrived at both by theory and by simulations using movement parameters like those measured for codling moth (Adams et al. 2017).

by documentation (Kehat et al. 1994, Vacas et al. 2013) that, although it might attract more codling moth males to the trap, doing so diminishes rather than raising overall catch. Apparently, trap entry rate is inhibited by excessive pheromone near the source (Huang et al. 2013). Another tactic might be to deploy multiple traps per 21 ha rather than one. Indeed, more codling moths would then be captured because of the guaranteed increase in summed plume area. However, Michigan fruit growers and pest management consultants are reluctant to deploy multiple monitoring traps per orchard, mainly because of the unacceptable time demands and thus costs required to travel to the various trap sites for servicing each one across the whole growing season.

In pondering this problem, we were struck by its parallels to the challenge fishermen face in needing to deploy multiple baited hooks across fish habitat while minimizing travel and service time per hook. A favored solution to this optimization problem in fishing is long-line fishing (Yamaguchi 1989, Otto and von Brandt 2005), where multiple baited hooks descend from short snood lines at increments from a tow-line. This configuration dramatically raises the probability of catch by summing the reaches of plumes emanating from all bait point-sources. Optimized spacing of snood lines from the main line essentially creates a continuous and potentially very long plume acting upon any fish intersecting the long line at any point. Competition between hooks is considered nonproblematic when their spacing approximates the plume reach of a single baited hook. Moreover, hooks and bait are inexpensive. It turns out to be far more efficient to retrieve the main line while servicing all hooks than to travel to a unique location to tend each hook.

Here, we tested the general hypothesis that the line-trapping approach can successfully be applied to trapping of insect pests like *C. pomonella*, where the plume from each trap is small (ca. 3 m; Adams et al. 2017). In this case, we deployed five traps, not literally from a line, but along a row of apple trees so as to be slightly more than one plume-reach apart. Thus, little more time and effort would be required for the pest manager to drive to and service this trap aggregation than is required for tending a single trap. The specific hypotheses tested here were 1) average codling moth catch for five traps spaced 4 m apart in a line will be only slightly lower than that for a trap operating alone, and 2) the precision associated with a mean catch of five traps in a line, hereafter referred to as μ5, will be substantially higher than that for a single trap.

Materials and Methods

The above hypotheses were tested using a paired experimental design whose treatments were 1) a single delta trap (Pherocon VI, Trécé Inc., Adair, OK) always baited with a new CML2 gray septum (Trécé, Inc.) containing (E,E)-8, 10-dodecadien-1-ol (codlemone) and held aloft of the Tanglefoot-covered cardstock liner by a pin through the trap roof and 2) a line of five such traps each separated by 4 m. Traps were hung in the upper third of tree canopies. The commercial apple orchards used were located near Sparta, MI, and detailed by Adams et al. (2017). The horticultural and management protocols were standard for this area and included some insecticide sprays. Because feral *C. pomonella* populations at these sites were so low as to yield barely one male per trap per wk, codling moths of mixed sex (1:1 M:F) were purchased from the SIR rearing facility in Osoyoos, British Columbia, marked by distinctive fluorescent powders, and released into the test blocks (see Adams et al. 2017 for details on handling, marking, and release). Each block of this experiment consisted of the above two treatments separated by

70 m, as shown schematically in Fig. 2. Pairs of treatments were separated from other pairs by at least 150 m. To guarantee sufficient sampling power for strong tests of the above hypotheses, 100 males along with 100 females were released at the four locations marked R in Fig. 2 at the beginning of each trial lasting only 1 wk, which exceeded the life span of purchased codling moth males. Six blocks of this experiment were set up simultaneously on each of the six dates collectively spanning the entire 2015 growing season, so as to yield 36 data pairs. The longest interval between replications was 3 wk. The position of the single trap versus the line-trap with respect to cardinal direction was balanced to guard against possible bias owing to prevailing wind direction that, during the daytime, was from the west. The data were collected nearly daily for each week-long replicate of this season-long experiment. *c. pomonella* males harvested from each individual trap were tallied after identification as wild or released. Statistical comparisons were made via paired *t*-tests on untransformed data.

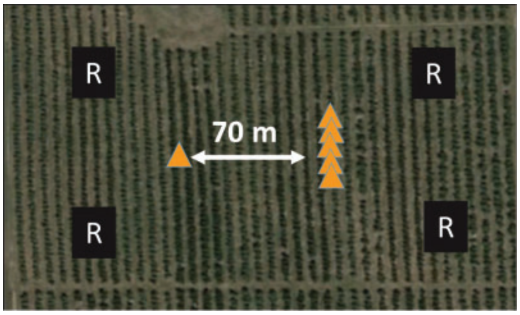

Fig. 2. Schematic of the layout for one block of the experiment comparing capture in a single trap (represented by a triangle) relative to that in a line of five traps each separated by 4 m; the distance separating triangles in the line is not drawn to scale. At each release point (R), 100 codling moth males were released at the start of each trial lasting 1 wk.

Results and Discussion

Feral males constituted <2% of all the *C. pomonella* captured, hereafter given as total catch. Mean weekly capture in the single trap was 6.2 ± 1.0 (S.E.M.; range 0–32) males versus 4.0 ± 0.6 (S.E.M.; range 1–12) for the μ5 measure. This 35% reduction was not statistically significant ($P = 0.15$). Thus, Hypothesis 1 is confirmed; the level of competition between traps spaced only 4 m apart is proven to be modest. As anticipated, the severity of competition increased significantly in the middle of the trap line compared with its ends (Fig. 3). Pleasingly, traps in a common position along the trap line performed nearly identically. Collectively, these data validate the notion that when reach of the plume from a trap is small as for *C. pomonella*, spacing multiple traps closely in a line can yield catches per trap almost as high as would isolated traps spaced widely.

The data of Fig. 4 confirm the claim (Hypothesis 2) that precision around μ5 will be substantially higher than that around the capture number for a single trap. Or, stated conversely, the variance for catch by a single trap is substantially greater than that for the mean of five traps in a line. Although the single trap occasionally caught no *C. pomonella* males per wk, such false negatives never occurred for the μ5 measure. Furthermore, the single trap occasionally registered catches of >15 males per wk, while this never happened in the μ5 measure. Startlingly, the single trap returned a catch of 32 *C. pomonella* males per wk on one occasion when the overall mean for the 36 replicates was only 6.2, proving single codling moth traps will sometimes return extremely variable catches. Catch data such as this would certainly lead to erroneous pesticide application of this falsely perceived hot-spot in the orchard.

The main conclusion of this study is straightforward. Deploying a single trap to monitor *C. pomonella* density in the 21-ha sampling area does a poor job of proffering a reliable estimate of the density of this pest. It is far better to deploy five traps in a line with trap spacing of ca. 4 m. The cost of the additional traps (US$11 per trap plus lure) is dwarfed by: 1) the savings that could be realized by withholding sprays when they are indeed not justified (ca. US$1,000 per

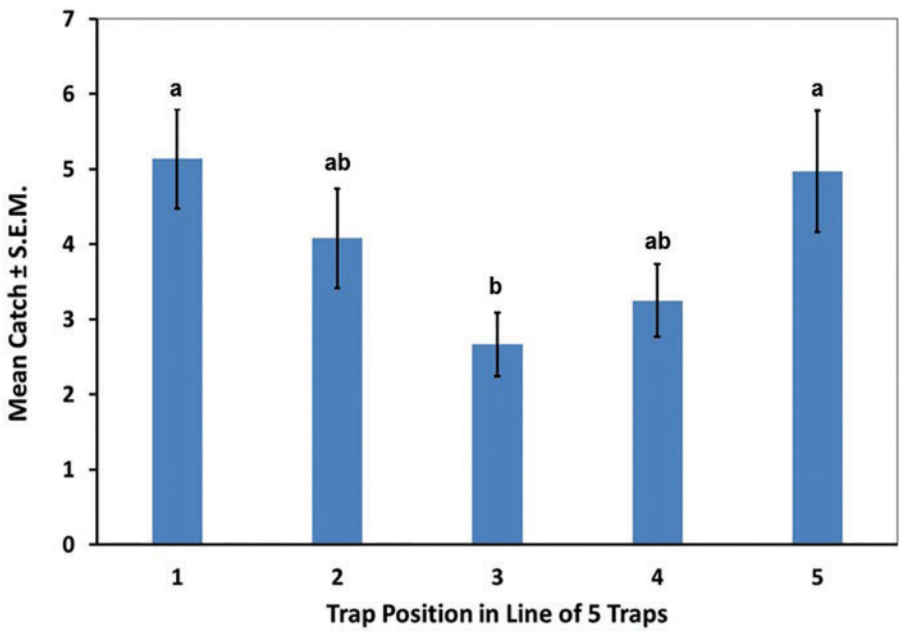

Fig. 3. Capture of codling moth males as influenced by their position in the line of five traps. Means sharing a common letter are not statistically different at $P = 0.05$, $n = 36$. Mean capture in a single trap was 6.2.

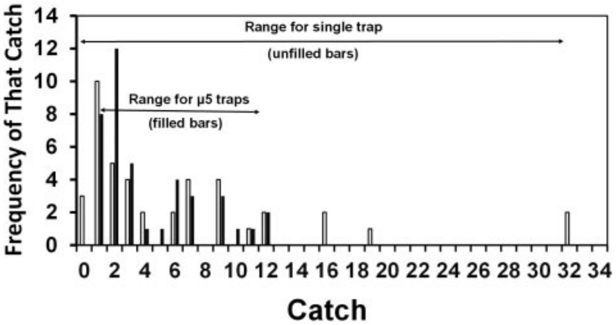

Fig. 4. Frequency histograms of field data showing the realized capture numbers of codling moth under the single trap (unfilled bars) versus μ5 configuration (filled bars) in Michigan apple orchards, $n = 36$. The range of the μ5 catch was 1–12, while the range of the single trap was 0–32.

codling moth spray per trapping area of 20 ha); or 2) the losses that could be realized because the single monitoring trap presented false negatives. Line-trapping is highly recommended when assessing pest densities under mating disruption, where catch numbers are suppressed by deployed synthetic pheromone. For example, our initial computer simulations demonstrate (data not shown) that the frequency histogram for probability of a particular catch of *C. pomonella* under mating disruption yielding 70% catch reduction flattens relative to the pattern seen in Fig. 4. A false negative would result >25% of the time a single trap like that used above is operative under mating disruption; however, that problem would be eliminated under line-trapping.

As the science of pest management matures by mastering the ability to translate capture numbers into estimates of absolute pest density (Miller et al. 2015, Adams et al. 2017), it will be important to employ a tactic like line-trapping so as to shrink the troublesome variability associated with capture numbers in single traps. It is likely that the advantages of line-trapping will be substantial even when plume sizes are moderate to large. Thus, the value of this approach may be far-reaching. For example, detectability of invasive species is critical and requires maximally powerful monitoring tools that reduce the possibility of false negatives. The detection power of the line-trapping tactic will rise correspondingly with the length of the trapping line. In certain cases, long-line and very long-line trapping could be justified.

Acknowledgments

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References Cited

Adams, C. G., P. S. McGhee, J. H. Schenker, L. J. Gut, J. Brunner, and J. R. Miller. 2017. Maximizing information yield from pheromone-baited monitoring traps: estimating plume reach, trapping radius, and absolute density of codling moth (*Cydia pomonella*) in Michigan apple. J. Econ. Entomol. 110: 305–318.

Gut, L., and J. Wise. 2016. Codling moth integrated pest management. pp. 109–113 *In* J. C. Wise, L. J Gut, R. Isaacs, A.M.C. Schilder, G. W. Sundin, B. Zandstra, R. Beaudry and G. Lang (eds.), 2016 Michigan fruit management guide. Michigan State University Extension Bulletin E154, East Lansing, MI.

Huang, J., L. J. Gut, and J. R. Miller. 2013. Codling moth, *Cydia pomonella*, captures in monitoring traps as influenced by proximity to competing female-like- vs. high-releasing pheromone point sources. J. Insect Behav. 26: 660–666.

Kehat, M., L. Anshelevich, E. Dunkelblum, P. Fraishtat, and S. Greenberry.1994. Sex pheromone traps for monitoring the codling moth: Effect of dispenser type, field aging of dispenser, pheromone dose and type of trap on male capture. Entomol. Expt. Appl. 70: 55–62.

Miller, J. R., C. G. Adams, P. A. Weston, and J. H. Schenker. 2015. Trapping of small organisms moving randomly: Principles and applications to pest monitoring and management, p. 114. Springer Brief in Ecology.

Otto, G., and A. von Brandt. 2005. Fish catching methods of the World, 4th edn. Blackwell Publishers, Oxford, United Kingdom.

Vacas, S., M. Miñarro, M. D. Bosch, J. Rrimo, and V. Navarro-Llopis. 2013. Studies of the codling moth (Lepidoptera: Tortricidae) response to different codlemone release rates. Environ. Entomol. 42: 1383–1389.

Weston, P. A. 1986. Experimental and theoretical studies in insect chemical ecology: Ovipositional biology of *Delia* flies and simulation modeling of insect movement. Ph.D. Dissertation. Michigan State University, E. Lansing, MI. U.S.A.

Witzgall, P., P. Kirsch, and A. Cork. 2010. Sex pheromones and their impact on pest management. J. Chem. Ecol. 36: 80–100.

Yamaguchi, Y. 1989. Tuna long-line fishing I: historical aspects. Marine Behav. Physiol. 15: 1–11.