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2017 - 29th Annual Conference Proceedings

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Recommended Citation

Price, William J.; Wenninger, Erik J.; and Shafii, Bahman Ph.D. (2017). "Modeling Potato Psyllid Occurrence Using Sticky Trap Data for the Management of Zebra Chip Disease," *Conference on Applied Statistics in Agriculture*. <https://doi.org/10.4148/2475-7772.1522>

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Modeling Potato Psyllid Occurrence Data Using Sticky Trap Data for the Management of Zebra Chip Disease

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Zebra chip is a disease of potato producing striped necrotic patterns that become pronounced when fried, and hence, making products such as potato chips and fries unmarketable. The disease is associated with a bacterium “*Candidatus Liberibacter solanacearum*” (Lso) and is transmitted by the potato psyllid, *Bactericera cockerelli*. Due to this pathogen-vector relationship, an important aspect in managing this disease is the modeling and prediction of potato psyllid occurrence. In this study, potato psyllid numbers were monitored regularly around potato fields across the southern Idaho region. This unique data set encompasses psyllid counts, collected by multiple sticky traps, collected at 98 growing sites across the region over 2013, 2014, and 2015 growing seasons. The resulting data are modeled using a modified nonlinear logistic growth function, which accounts for the negative skewness that is inherent in this sticky trap data. The estimated models are subsequently used to compare relevant potato psyllid occurrence parameters between major growing regions of southern Idaho. Comparisons of various trap configurations within each region were also carried out among estimated model parameters.

Results from this modeling effort could help researchers and growers efficiently monitor the psyllid populations and anticipate the potential for future disease outbreaks.

I. Introduction

Idaho is the leading potato production state with 30% of national production and 50% of processed products. Zebra chip, however, could potentially reduce marketable yields in the state. This disease is new to Idaho and was first identified in 2011. It is caused by the bacterium “*Candidatus Liberibacter solanacearum*” (Lso), which produces striped necrotic patterns in the potato flesh that become pronounced when tubers are fried. This discoloration renders products such as potato chips and fries unmarketable. The bacterium itself is spread by an insect vector, the potato psyllid (*Bactericera cockerelli*). Management of zebra chip disease concentrates on controlling the potato psyllid vector. Treating fields for psyllid can be costly. In the year 2012, it was estimated that the costs associated with controlling potato psyllids were \$40-\$150 more per acre than the previous year, when the disease in Idaho was first noted.

Efficient management of the potato psyllid will require an ability to predict where and when potato psyllid occurrence is likely to happen during a particular growing season. The work here was carried out to begin addressing the prediction problem for potato growing regions in southern Idaho. Results will be demonstrated using sticky trap data collected as part of a larger multi-site, multi-year monitoring program.

II. Methods.

Data Description

Commercial potato fields were monitored over four growing seasons (years 2012-2015) covering three geographic potato growing regions of southern Idaho. As part of this larger project, yellow sticky traps were used to collect adult psyllids, beginning with emergence and continuing through harvest. As a means of gauging sampling efficiency, two different sampling schemes for sticky trap were investigated: Intense sampling - 10 cards around the field at 13-16 locations each year; and Light sampling - 4 cards around the field at 77-94 sites/year. Each position had cards facing both towards, and away from, the potato crop. The count data for each trap card side were recorded at weekly intervals.

Considerable spatial and temporal variability in the psyllid counts were evident due to changes across sites and years. To mitigate these effects, weekly calendar dates were converted into relevant local degree day measurements using the rectangular method with a lower developmental threshold of 7.1°C and a biofix date of 1 January. Additionally, the raw card counts were converted to cumulative proportions over the growing season, relative to the observed maximum for each site-season. Finally, observations from the 4-10 cards per field were averaged for each card side.

Model and Estimation

Cumulative biological data are often described using an S-shaped logistic form similar to:

$$\hat{y} = \frac{1}{1+e^{-B(dd-L)}} \quad (1)$$

For the potato psyllid data, $\hat{y}$ would be the predicted cumulative proportion, B describes the rate of change, dd are degree days and L is an offset, or in this case, the number of degree days to reach a cumulative proportion of 50%.

This basic logistic form, however, assumes a symmetric distribution, while many biological processes are right skewed, showing a rapid initial response that peaks early and then slowly tapers off to zero. The phenomenon is often accounted for in the model by using a log-logistic form, i.e. assuming symmetry on a log scale (e.g. Price et. al, 2012):

$$\hat{y} = \frac{1}{1+e^{-B((\ln(dd) - \ln(L)))}} \quad (2)$$

The potato psyllid data, however, had a distribution which exhibited a left skewedness that started slowly, and then peaked and declined late in the growing season. In order to adjust for this, the degree day scale was reversed through a transformation of variables by subtracting the weekly degree day values from the observed maximum degree day within each site-year, Max_{dd} . This transformation essentially flips the distribution about the horizontal axis, converting a left skewed form to a right skewed form, which is more amendable to the log-logistic model. The above conversion is accomplished by rewriting (2) as:

$$\hat{y} = \frac{1}{1+e^{-B((\ln(Max_{dd} - dd) - (\ln(Max_{dd} - L)))}} \cdot \quad (3)$$

In practice, the results from (3) can be re-expressed on a de-cumulated scale making the predictions interpretable as weekly occurrence throughout the season. In this form, parameter L represents an inflection point, or the degree day at which maximum infestation will occur.

Estimation of (3) was carried out through a generalized nonlinear mixed model (Pinheiro and Bates, 1995). The cumulative proportions were assumed to follow a beta (π , ϕ) distribution

with π estimated by (3) and ϕ as an additional dispersion parameter. Spatial - temporal variability due to site-years was accounted for by assuming a random effect, ε , on parameter L , where $\varepsilon \sim \text{normal}(0, \sigma^2)$. Models were initially estimated separately for trap card sides as well as the different growing regions. Following model assessment, dummy variable regression techniques were used to compare parameter estimates between the two card sides or growing regions. All estimation and graphics were carried out using SAS 9.4 (2012).

III. Demonstration

Only two of the three potato growing regions, the Treasure Valley and the Magic Valley (Figure 1), had sufficient data for modeling.

Figure 1. The Treasure Valley and Magic Valley Potato growing regions of Idaho.

While full analysis of both sampling schemes was carried out, this demonstration will concentrate on the intense sampling scheme (10 traps/site) data.

Models were estimated separately across all site-years for the two trap side categories (inward and outward from the potato field) within each growing region. The estimated curves fit the data well (e.g. Figure 2: Treasure Valley) and all parameter estimates were significant (Tables 1 and 2). In the Treasure Valley, psyllid occurrence showed an inflection point of about 1800 degree days, while that for the Magic Valley was about 1500.

Figure 2. Estimated logistic curves for the cumulative proportion of potato psyllid capture in the Treasure Valley. Panels represent data from sticky trap cards facing away from (A) and towards (B) the potato fields.

Table 1. Logistic curve parameter estimates for the cumulative proportion of potato psyllid capture in the Treasure Valley. Rows represent estimates from sticky trap cards facing away from (1) and towards (2) the potato fields.

Treasure Valley

Card Side	Parameter	Estimate	Standard Error	Pr > t
1	<i>B</i>	4.1	0.5	<.0001
	<i>L</i>	1798.2	42.1	<.0001
2	<i>B</i>	3.6	0.4	<.0001
	<i>L</i>	1751.3	45.4	<.0001

Table 2. Logistic curve parameter estimates for the cumulative proportion of potato psyllid capture in the Magic Valley. Rows represent estimates from sticky trap cards facing away from (1) and towards (2) the potato fields.

Magic Valley

Card Side	Parameter	Estimate	Standard Error	Pr > t
1	<i>B</i>	3.7	0.6	<.0001
	<i>L</i>	1520.0	97.8	<.0001
2	<i>B</i>	3.5	0.5	<.0001
	<i>L</i>	1540.0	102.3	<.0001

Within each growing region, it was of interest to compare the two card sides in order to assess directionality of psyllid immigration into the potato fields. A full dummy variable model incorporating the two cards sides was used to test for equivalence of the two estimated models

(Figure 3; Table 3). No significant differences in the trap side models were found in either growing region. Trapping data were considered to be equivalent from inward and outward facing sticky traps.

Figure 3. The predicted left skewed logistic curves for the Treasure Valley growing region. The two curves represent sticky trap data from cards facing away (1, blue solid line) and towards (2, red dashed line) the potato fields.

Table 3. Full dummy variable contrasts comparing estimated logistic model lines and parameters of inward and outward facing sticky traps in the Treasure and Magic Valley growing regions.

Treasure Valley		Magic Valley	
Contrast	Pr > F	Contrast	Pr > F
Lines	0.5329	Lines	0.9428
Rates (<i>B</i>)	0.5137	Rates (<i>B</i>)	0.7475
Onset (<i>L</i>)	0.4641	Onset (<i>L</i>)	0.8278

Given these non-significant results, the side data were subsequently pooled to provide a “total” relative count response per card and a single model was re-estimated for each growing region (Figure 4, Table 4).

Figure 4. The estimated total psyllid count logistic curve fits for (A Treasure Valley and b) Magic Valley.

Table 4. Parameter estimates for the logistic models predicting total psyllid catch on sticky traps in the treasure and Magic Valley growing regions.

Treasure Valley

Parameter	Estimate	Standard Error	Pr > t
<i>B</i>	3.5	0.1	<.0001
<i>L</i>	1775.2	77.5	<.0001

Magic Valley

Parameter	Estimate	Standard Error	Pr > t
<i>B</i>	3.7	0.4	<.0001
<i>L</i>	1520.0	87.0	<.0001

While the results for the Treasure Valley were similar to previous results, those for the Magic Valley differed slightly from the initial fits. The Magic Valley data were more variable and the estimated inflection point, *L*, was smaller than the previous estimates.

The de-cumulated model form is more interpretable for practitioners, showing the rate of change in psyllid occurrence throughout the growing season. The inflection point (parameter *L*) in this form indicates the point in time of peak infestation. The two estimated regional models

were transformed in this manner for reporting (Figure 5). Here, the faster infestation rate of the Magic Valley is clearly evident.

Figure 5. The predicted de-cumulated psyllid occurrence models for the Treasure Valley (red) and Magic Valley (blue) potato growing regions.

As a means of comparing psyllid infestations across the two growing regions, a second full dummy variable model incorporating the two regions was fit and contrasts comparing the two curves, as well as the individual parameter estimates, were carried out (Table 5). While the Magic Valley indicated a lower number of degree days for peak infestation, the difference in the full model assessment was non-significant. This lack of significance is likely due to the higher level of variability in the Magic Valley data. Further discrimination and assessment of the sites within the Magic Valley region may be necessary to diagnose the underlying source of the variability, which may in turn lead to a more precise model estimation.

Table 5. Full dummy variable contrasts assessing coincidence of lines and individual parameters of the estimated logistic curve fits for psyllid occurrence data in the Treasure and Magic Valley potato growing regions.

Contrast	Pr > F
Lines	0.6277
Rates (<i>B</i>)	0.8977
Onset (<i>L</i>)	0.3672

IV. Concluding Remarks

Nonlinear modeling of sticky trap data provides a useful tool for monitoring and managing potato psyllid and the associated zebra chip disease in Idaho. For this type of occurrence data, however, the left skewed nature of the count data over time is not amendable to standard nonlinear logistic model analysis. A transformation (reversal) of the regressor axis (cumulative degree days) may be used as a corrective measure, producing a right skewed data pattern that can be modeled using standard nonlinear logistic techniques.

Sticky trap monitoring data collected over four years and multiple sites across southern Idaho were modeled in this manner. Models were estimated separately for different trap sides within two major potato growing regions. Comparison of the estimated models indicated no significant differences in inward or outward facing trap sides. Further assessment of the models

was then carried out for similarities of the growing regions. Although the Magic Valley model estimates suggested that peak psyllid infestation may occur earlier in the season relative to the Treasure Valley, no significant differences were found between the predicted models of each region. The higher variability observed in the Magic Valley data, however, may have masked this potential difference. While the source of this higher variability is not yet identified, doing so will be desirable to obtain a more precise estimation of the model for that region. The estimated models reported in this study represent an initial step towards predicting the occurrence of potato psyllid infestation, and by extension, zebra chip disease. Before implementing these models, however, further work will be required to validate their reliability.

V. References

- Pinheiro, J. C and D. M. Bates. 1995. Approximations to the Log-Likelihood Function in the Nonlinear Mixed-Effects Model. *Journal of Computational and Graphical Statistics* 4, 1:12-35.
- Price, W. J., B. Shafii, and S. S. Seefeldt. 2012. Estimation of Dose–Response Models for Discrete and Continuous Data in Weed Science. *Weed Technology*, 26:587–601.
- SAS Institute Inc. 2012. SAS OnlineDoc® 9.4. Cary, NC: SAS Institute Inc.