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Temporal Variance-Mean Relationships for Logarithmic-transformed Insect Catches in Light Trap Samples Adjusted for Lunar Phases

Sujata Mukherjee[1] and Joe N. Perry
Rothamsted Experimental Station,
Harpenden, Hertfordshire, AL5 2JQ United Kingdom
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SUMMARY

Counts of a major insect pest were sampled in light traps at seven sites, and adjusted from nightly catches to a lunar phase time scale. Logarithmic transformation of these data was shown to be insufficiently severe to equalise their variance. Taylor's power law for temporal variance gave an excellent fit to the logarithmically-transformed data and enabled precise estimation of the degree of remaining dependence of variance on mean. The degree of temporal variation was shown to differ between two groups of the seven sites, and the difference was estimated. The implications of these results are discussed for statistical transformations, assessment of site variability, and sampling of insect pests.

Key words : Temporal variance, Lunar phases, Lunation, Variance estimation, Linear regression, Taylor's power law, Sampling, Insect pests.

1. Introduction

Insects sampled by light-traps show variability in daily catch both between different months within a year and between years. Catches may range from a count of zero to thousands. The means and variances of catches within a year usually differ, both for different years and for different locations. For such data, the variance is usually dependent upon the mean and requires stabilization. A transformation [5] based on Taylor's power law [11] makes the variance of the transformed catch independent, to first order, of its mean.

However, light-trap samples (LTS), taken during the period from dusk to dawn, may also require correction for the effect of the background illumination of moonlight [1]. The nightly catch, n, is first logarithmically transformed to $t = \log_{10}(n + 1)$, and the time scale is then changed from

1 *Research Scientist (Honorary) B 14/168 Kalyani 741235 District-Nadia West-Bengal, India*

calendar date to a lunar phase, where there are 32 phases in an entire lunation of 29.53 days [2]; adjusted values of t are denoted as l.

In this paper, our primary aim is to study LTS for a serious insect rice pest [7], to investigate whether the logarithmic transformation is sufficient to provide homogeneity of variances for values of l, as required for further analyses. We use a method [12] that fits a power-law variance-mean regression relationship to sample means, m, and variances, s^2, over time :

$$E\,[\log_{10}s^2] = \log_{10}a + b\log_{10}m$$

where E [] denotes expectation. A secondary aim is to assess possible differences in the temporal variation of LTS between sites.

2. *Methods*

The LTS data concern the rice green leafhopper (GLH), *Nephotettix* spp., from seven sites in West Bengal ([6], [8], [9]). In that analysis, sites 1, 2, 3, 4 (group 1) gave different results from sites 5, 6, 7 (group 2); group 1 were all double-cropped areas, group 2 were monocropped. Sites 5 and 6 were considerably larger fields than the rest; also, site 7 was in semi-arid region, a substantial distance to the west of the others. The value of l for each lunar phase was calculated ([2], [3]). The sample mean, m, and variance, s^2, of the l values were calculated over the entire set of phases, for each site separately. Estimates of the parameters $\log_{10}a$ and b were obtained from these m, s^2 pairs by ordinary least-squares regression [10]. Differences between these parameters for the two groups of sites were studied by analysis of parallelism using the Genstat statistical package [4].

3. *Results*

The simplest model fitted, representing a single regression line, provided a poor fit, with considerable residual variation, yielding a non-significant regression, as shown in Figure 1. The second model fitted represented two parallel lines that allowed for differences in the intercept parameters, $\log_{10}(a_1)$ and $\log_{10}(a_2)$, between the two groups of sites. This provided an excellent fit (Figure 1, Table 1), explaining 97.8% of the variance ($F_{2,4}$ = 136, P < 0.001). The estimated value of $\log_{10}(a_1)$ for group 1 (sites 1-4) was 0.248 (s.e. = 0.0164) and that of $\log_{10}(a_2)$ for group 2 (sites 5-7) was 0.531 (s.e. = 0.0185), and the estimated slope, b, was 0.338 (s.e. = 0.117).

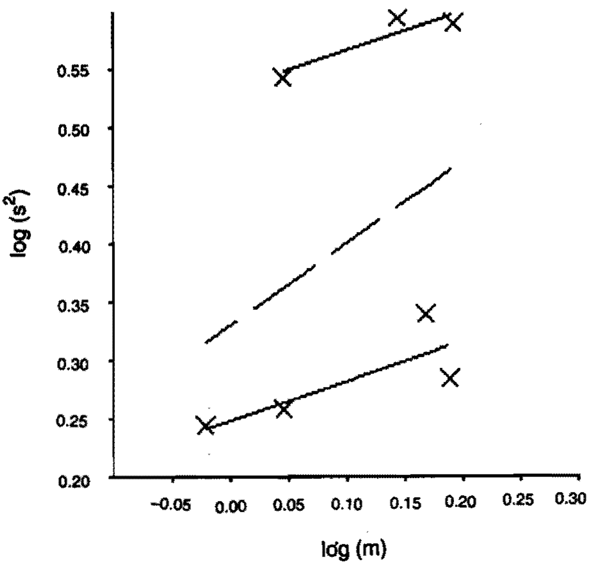

Figure 1

Observed and fitted data for the logarithmically- transformed catch in light traps of the rice green leafhopper expressed per lunar phase, l at seven sites. Sample variances, s^2, and sample means, m of l values over time fitted by Taylor's power law for temporal variance. Dashed regression line shows a poor fit to the data when the seven sites are considered as a single group. Solid parallel regression lines show an excellent fit when the sites are split into two groups on the basis of ecological considerations, and reveal strongly significant regression coefficient.

Table 1. Data and results for temporal power-law relationship

Site ref. no.	Site group	Number of lunar phases	$\log_{10} m$ (observed)	$\log_{10} s^2$ (observed)	$\log_{10} s^2$ (fitted)
1	1	799	0.047	0.257	0.264
2	1	491	0.169	0.339	0.305
3	1	463	0.189	0.283	0.312
4	1	489	0.020	0.243	0.241
5	2	157	0.047	0.542	0.547
6	2	159	0.192	0.589	0.596
7	2	160	0.145	0.573	0.580

4. Discussion

The significant regression in the second model, with the substantially positive estimate of b of 0.338, indicates that the logarithmic transformation was insufficiently severe to equalise the variances of the raw counts, and implies that any further analyses of l should account for this remaining dependence of the variance of l upon its mean. This is unusual; typically insect pests require a transformation between the square-root and logarithmic ([5], [11], [12]). Few studies check whether a particular chosen transformation is appropriate; these results caution that such confirmation should be sought more often.

Furthermore, the magnitude of the difference in estimated intercepts, 0.283, for the two groups of sites shows that the predicted variance for l values at sites in group 2 was almost twice that for group 1. This result confirms the importance of the agronomic differences listed above and noted elsewhere [7]. Another contributory factor to the dissimilarity in temporal variability might have been that the personnel involved in data recording differed between the two groups. Figure 1 emphasizes that a naive analysis, in which the sites were considered as a single set, would produce considerable bias in estimates of b. These results demonstrate the importance of care in the estimation of the parameters $\log_{10}$ a and b, which are used widely [3] in the derivation of efficient sampling schemes for major agricultural pest species.

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