

Thresholds/Monitoring/Sampling

Influence of the Moon on Pheromone Trap Captures and Generation Emergences of Codling Moth in Southern California (Kern County)

Janet Conlee

Keywords: codling moth, moon

Abstract: Ten years of daily sex pheromone-baited trap capture data for the codling moth [*Cydia pomonella* (L.)] were analyzed for lunar periodicity, using both statistical and nonstatistical methods. Using time series (spectral) analysis, a sine wave periodicity of approximately 30 days was detected in 6 of 10 annual spectra and at a significance level of $P < 0.05$ in a combined 10-year spectrum. Autoregression analysis failed to detect precise periodicity and showed that these trap captures are independent after 3 days. Frequency distributions of generation emergences over 10 years showed that 80% occurred within 3 days of either a new or full moon. First true generation emergence was found to change according to coincidence of the lunar periodicity to annual constraints, and second generation emergence occurred 43.4 days (1.5 lunar cycles) later. A hypothetical model for this was developed and its potential accuracy compared with that of published degree-day models. **This model has accurately predicted first and second generation codling moth emergences in southern California during the past two years.**

Summary and Conclusions

1. The spectral analysis of daily sex pheromone-baited trap capture data indicate that many years of season-long data, with **moderate to high population levels may be necessary to discern the presence of lunar periodicity.**
2. **Sex pheromone-baited trap captures of codling moth show a lunar periodicity.** This conclusion is based on the spectral analysis of the individual annual spectrum for the years 1983 to 1992 and of a combined spectrum for all 10 years of data. The analysis of each annual spectrum indicates that a frequency in the neighborhood of 30 days is present in 6 of the 10 years studied, these being the later years with higher population levels. A significant ($P < 0.05$) spectral peak in the neighborhood of a 30-day periodicity is present in the analysis of the combined spectra of all 10 years. However, this periodicity is a relatively weak "signal" underlying the great day-to-day variability caused by all the other "noise" factors, such as weather, affecting trap captures.
3. **Unexpectedly, 45-day and 60-day periodicities are present in the trap capture data,** this conclusion also being based on the spectral analysis of the individual annual spectrum and the combined spectrum for all 10 years of data. Although the simultaneous occurrence of both spectral peaks occurs only once in the annual spectra, both peaks appear at a level of significance ($P < 0.05$) in the combined spectrum due to pooling of data.
4. **Sex pheromone-baited traps used to monitor codling moth populations should be**

checked at least every three to four days, but no advantage is gained for general pest management purposes by checking traps more frequently. This conclusion is based on the autoregression analysis of the trap capture data which showed that the number of insects caught is independent after 3 days, possibly a result of changing weather conditions.

5. **Emergences of codling moth generations are closely related to the changing cycles of the moon.** This conclusion is based on the results reported herein for the frequency distribution evaluation of emergence dates for all emergences during the 12 years of data studied, which showed that **80% of these events occurred with 3 days of either a new or full moon.** It is also reported by the large number of reports of lunar emergence rhythms in aquatic and semiterrestrial insects and the adaptive advantages that such a periodicity in emergence might have.
6. **The first generation emergence of codling moth changes each year in relation to where the 30 day lunar periodicity falls in relation to an annual constraint on this emergence event.** This conclusion is based on the data presented which show the emergence of this generation changing over the 12 years of data studied from a new to a full moon event, dependent upon which one falls within the apparent annual constraints on this event. There is evidence in the literature that this might be photoperiodically controlled.
7. **The pooling of data into a single lunar series prior to analysis in previous studies may have obscured the changing relationship between moon phase and generation cycles.** This conclusion is based upon the results presented where, in the spectra analysis of data, the pooling of the annual spectra into a combined spectra lead to the significant presence of two spectral peaks; whereas, in individual spectrum, only one or the other was normally present. This indicates that generalizing about pooled data may have led to some of the confusion in the literature concerning the nature of lunar periodicity.
8. **A 19-year cycle of coincidence between the lunar cycle and calendar days may be influencing the emergence of the first and second (true) generations of codling moth.** This conclusion is based upon observation of an overall trend for these emergences to occur at a progressively earlier date over the 10 years of data examined, indicating that a reversal of this trend is likely. The probable reversal of this trend may be related to the return of the same moon phase to the same calendar day in another 9 years, with the trend over these years for the emergence date to shift back to a progressively later date.
9. **The 10 years of data for the first and second generation emergences of codling moth indicate that a lunar-based predictive model for these occurrences could be constructed.** Following field validation, this predictive model has the capacity to be more accurate than current degree-day (DD) models to predict emergence events. This conclusion is based upon observations presented about the apparent "rules" of the changing relationship of emergence to moon phase and a comparison of the accuracy in this relationship compared with the published accuracy of DD models to predict this event (in CA). This conclusion is also supported by the literature which indicates that

biological rhythms are a powerful influence on physiological development and are temperature compensated and not mediated, as long as temperature is not limiting.

10. **The hypothetical model has been accurate the past two years in predicting first and second generation codling moth emergences in southern California.**
11. **The combination of a lunar emergence model and a DD model could have potential usefulness in pest management with the lunar-related periodicity predicting the date of beginning of emergence and DD models predicting the degree of response once the emergence "gate" is opened.** This conclusion is extrapolated from the biological rhythm literature on what is known about emergence rhythms in relation to temperature.
12. **Future field validation of a lunar-related emergence predictive model and its integration with DD models could lead to a greater understanding of temporal programming in the codling moth and aid in developing more efficient monitoring and control practices.** There is evidence that lunar rhythms are latitudinally affected and it is interesting that DD models work better in northern as compared to southern latitudes. It would be of value to conduct a comparative study of this data from southern California with data from more northern latitudes. It is also possible that other insects may similarly show a changing relationship in emergence to the changing cycles of the moon, and a greater understanding of this phenomenon might lead to improved forecasting of other insect pest generation emergences as well.