March, April = 100
May, June, July and August = 30
September and October = 100
November, December, January and February = 400

Figure 3. Martin's basic model structure of the varroa life-cycle. The numbered compartments refer to the various model elements.

cluded the number of eggs a foundress mite lays in different cell types and the resulting offspring survival statistics.[14,15]

The part of his research that has the most practical value to beekeepers is his model's ability to predict the total live mite population over time plus the daily rate of mite population increase. The model also showed the variation in mite population that occurs seasonally, and Martin claimed that a seasonal multiplier he developed could be used with a sticky board count to estimate the total mite population anytime a count is done.

While a model is a convincing calculation, its accuracy and usefulness depend on the model maker. In this case, Martin seemed to have an informed understanding of population dynamics. But even when a model's author gets it correct, all models are a simplification[18], and as discussed by Rosenkranz et al. (2010),[21] natural systems have a considerable amount of variation. Therefore it's important to enhance a model with additional research and in particular with relevant field research. Although in Martin's paper he suggests there was some form of field research, in recent correspondence, he indicated that any field data was likely lost.

Supporting Field Work

In a paper by Branco, et al. (2005),[5] the authors compared three sampling methods using 22 live colonies carried out over a two-year period.

The first method in Branco's study combined the total mite counts from both alcohol washes and from uncapping of brood cells. Based on some earlier science,[19] combining these two totals was considered a more reliable method than either done separately. Second, natural mite drops using sticky boards were done over five separate one-week periods resulting in 63 independent data samples.

The third sampling method was used to determine the total mite population. By estimating the total mite population, you can mathematically determine the extent to which the data gathered in the first two methods is related to that population. The only way to do that is to kill as many mites as you can and count them. In this study, they used Apistan strips (fluvalinate) which, at the time, were still very effective at killing mites. After the strips had been applied, the dead mites were collected on drop boards and counted weekly for six consecutive weeks. That total six-week count was then considered equal to the entire mite population.

After some regression testing,[22] the results showed that sticky board drop data could be considered a reliable predictor of the total mite population. In mathematical terms, the datasets showed a high correlation. Branco did not find the same correlation between the combined mite counts from the first method which used alcohol washes and uncapped brood. Also, Branco's natural drop periods were a week long which gives us our first hint about sticky board drops- the longer they are allowed to collect data the more accurate they are.

Branco also had to remove eleven outliers from the samples because they skewed the results. The need to remove outliers highlights the second major consideration for natural mite drops. The natural mite drops became unreliable when a colony remained broodless, or the colony was collapsing due to parasitic mite syndrome. Sticky boards are not considered accurate if a colony suffers from either of those conditions or any condition that would disturb brood rearing. Therefore, beekeepers using sticky boards should always consider doing a simple inspection beforehand to determine the overall health of the colony.

A more recent field study by Flores et al. (2015),[7] designed to test the accuracy of various sampling methods, concluded that a four-day natural drop using sticky boards is all that's required to obtain a significant correlation to total mite population. Flores tested alcohol washes, powered sugar rolls, and mite samples from uncapping brood cells. In all cases, the only significant correlation to total mite population was the natural mite drop. Flores used a four-day sample because the detritus accumulating on the drop board with longer intervals complicated counting mites. But Flores acknowledges that the longer the sample, the better the reliability. The four-day drop is a good compromise between accuracy and practicality. I've done many longer drops and can attest to the fact that hive detritus can make counting very difficult.

Summary

The original work by Martin, suggests that a simple multiplier can be used to translate the average daily number of mites found on a sticky board into the total mite population. Martin also suggests that the daily average multipliers can be adjusted seasonally to account for the natu-

MONTH COLONY MONITORED	TOTAL MITE POPULATION
January–May	170
June	300
July	500
August	1000
September	2000
October to December	2500

Figure 4. Martin's daily average drop multipliers by month obtained from his work in 1998. Once a colony's daily average drop is obtained in any given month, multiplying that average by the number for that month will yield an approximation of the total varroa population.