EMERALD ASH BORER FLIGHT ESTIMATES REVISED

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ABSTRACT

Using computer-monitored flight mills, we found that tethered emerald ash borer (*Agrilus planipennis*) adults can fly up to the equivalent of 2.8 km/day at speeds greater than 1.5 m/sec (3.5 mph), with mated females flying twice as far as unmated females ($P < 0.0001$), suggesting that gravid females are programmed to make dispersal flights. This is supported by the absence of a correlation ($R^2 = 0.0005$) between distance flown and female size (Figure 1). Females "flown" for 8 hours per day and then allowed to rest, feed, and drink for 16 hours continued to make long flights for up to five days: the maximum distance flown was 9.84 km in four days, with 50 percent of beetles flying over 4 km per day and 10 percent flying over 7 km per day.

It is difficult and can be misleading to draw conclusions about free flight from flight mill data. There are at least four potential sources of error in the assumption that *flight mill speed = true flight speed of the insect in free flight:*

- Inertial drag of the armature (work expended turning the armature)
- Torsional drag of the magnet (dynamo effect)
- Inconvenience of being attached to the armature (glued at the pronotum)
- Lift provided by the armature (all flight effort results in forward motion).

Thus, it is not clear whether true flight speed is greater or less than the speed recorded on a flight mill. Flight mill data are best interpreted relatively, as we did when comparing flight by males, unmated females, and mated females. In order to be able to draw conclusions about flight in the wild, flight mills must be calibrated: there are very few instances in which this has been possible.

Free flight speed estimates were obtained using high speed photography of beetles flying in a space between two mirrors as part of an experiment to determine the maximum feasible load for a beetle with a weight glued to the pronotum. The position in three dimensions of a flying beetle was determined by analysis of the position of the beetle and its two images in each film frame. An average speed was calculated from the change in position of each beetle from frame to frame. Figure 2 shows the relationship between flight speed and load as a percentage of beetle weight. The regression equation was used to remove the effect of weight from the flight speed to obtain a distribution of free flight speed. Figure 3 shows the mean flight speed in free flight to be three times that of the mean flight mill speed; the standard deviations are not significantly different ($t = 0.70$, $p > 0.48$) and neither distribution is significantly different from normal. Thus, we conclude that the impact of the flight mill is to reduce the measured flight speed by a factor of three. Assuming the duration of EAB flight on the flight mill is not greater than the same individual would achieve in the wild, we now revise the distribution of flight distance up by a factor of three (Figure 4; note the logarithmic abscissa), which predicts that 10 percent of gravid females are capable of flying over20 km per day.

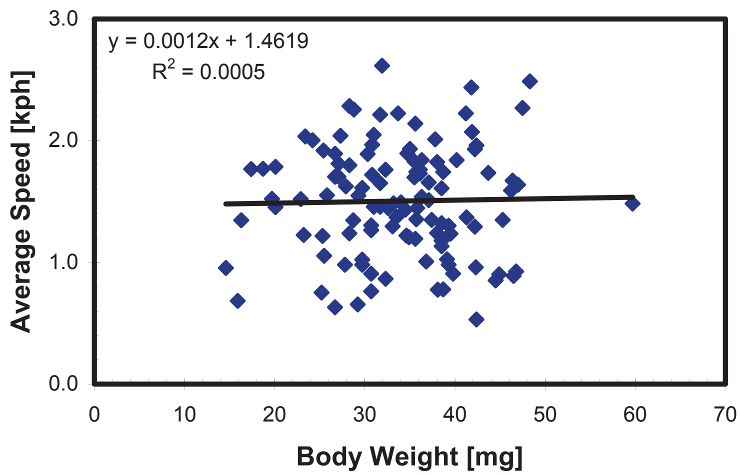

Figure 1: Effect of beetle size on female flight speed.

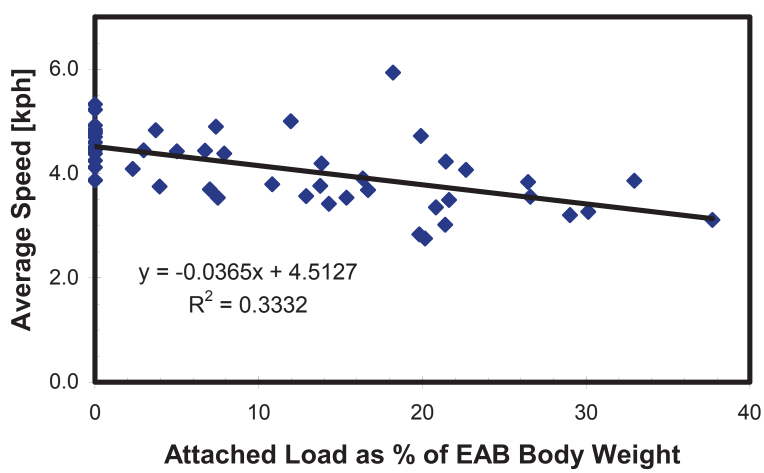

Figure 2: Effect of payload on female flight speed.

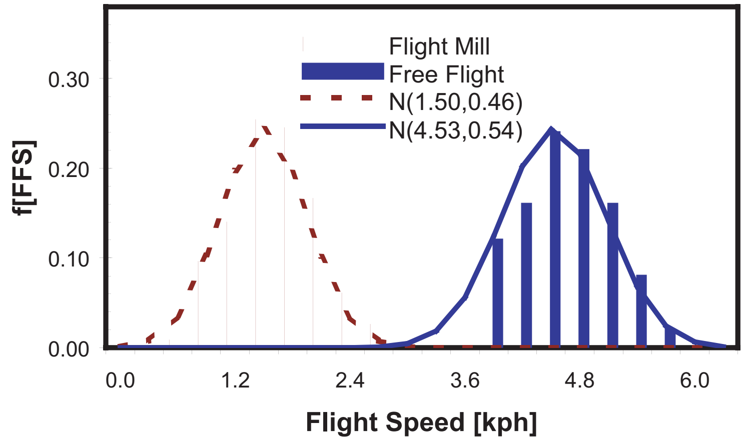

Figure 3: Distributions of female flight speed.

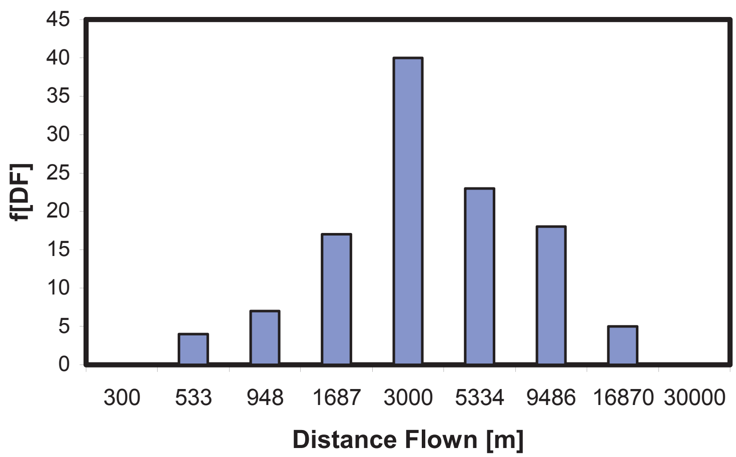

Figure 4: Predicted flight range of gravid female EAB.