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Locating and tracking large insects using radio telemetry

Options for radio-tracking insects are limited. Large insects like the Monarch butterfly weigh ca. 0.5gm and can carry transmitters weighing up to 0.3gm without effects on flight behaviour. Such lightweight transmitters are commercially available but have simple low power signals. This is quite different from the multiple technologies available to track medium- and large-sized animals. We found that traditional location-finding methods, e.g., triangulation using bearings with the strongest received signal, do not work with lightweight transmitters.

We deployed an automated radio telemetry system that records received signal strength (RSS) from each of 16 antennae placed on four towers at the corners of the study area. The goal is to locate and track monarch butterflies carrying 0.3gm transmitters in a field approximately 350m x 350m.

Certain features of this system complicate estimating the transmitter location: measurements from the same location have large variance, measurements are not synchronous, measurements below a lower threshold are not recorded, and antennae sample different parts of the study area.

We develop models that relate RSS to the distance and angle between the signal source and the antenna. These models include physically-based relationships between RSS and distance, empirical approximations for the relationships between RSS and angle, left truncation of RSS at the lower recording limit, and random effects to account for variability between antennae sampling different parts of the field. These models were fit to calibration data from known locations, then used to estimate unknown locations of stationary transmitters and tracks of moving transmitters.

Locations of stationary transmitters are estimated by inverse prediction from a fitted RSS model. Moving animals were tracked using a continuous time Hidden Markov Model fit to a time series of RSS. Location accuracy varied between 10m to 18m in the center of the field (usable data from 4 towers) and 15m to 22m near one of the towers (usable data from 2-3 towers). Confidence regions, estimated from sums-of-squares contours or Bayesian credible intervals, are far from bivariate normal.