Estimating true ranges of fossil taxa from stratigraphic data when recovery potential is not uniform

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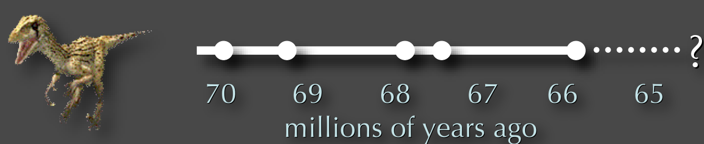
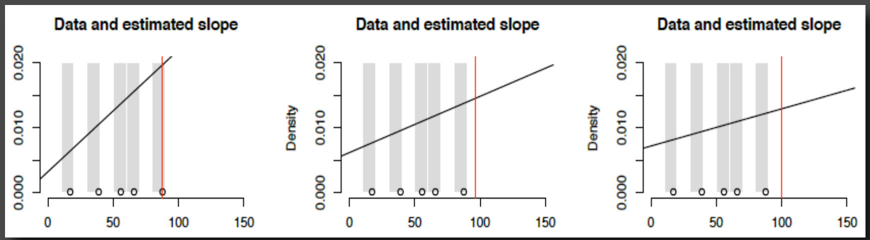
Paleontologists often want to determine the time of extinction of a fossil taxon (e.g., a kind of dinosaur). However, this task is made difficult by the incompleteness of the fossil record. For example, the dinosaur below is known from 5 fossil specimens, the most recent of which is dated to 66 million years ago:



Thus this dinosaur species went extinct more recently than 66 million years ago. But since there are gaps in the fossil record, it is possible that the dinosaur existed later than that time, and we are simply missing its fossils. In other words, the known stratigraphic range of a taxon probably underestimates its true range.

If we assume the probability of finding a fossil—the recovery potential—is uniform throughout the taxon's true range, then it is straightforward to estimate the true time of extinction. This assumption is often invalid, however, due to variations in rock availability or taxon abundance. Our goal is to estimate the true time of extinction without assuming uniform recovery potential, and without requiring a priori knowledge of the recovery potential (as some existing methods do).

Our iterative procedure alternately estimates the slope of the recovery function (assumed to be linear) and the true extinction time. In a simulated dataset, the first iteration (left panel below) overestimates the slope and underestimates the extinction time:



Open circles represent fossil finds. Black line represents the estimated slope. Red line represents the estimated extinction time. The true extinction time for these simulated data was set at time $t = 100$.

As the algorithm iterates (middle panel), we use the slope estimate to revise the estimated extinction time, and then use the revised extinction time estimate to revise the slope estimate. By alternately updating both estimates, the algorithm converges on improved estimates of both quantities. By the third iteration (right), the estimated extinction time closely matches the true extinction time.

We next plan to extend our methodology to calculating confidence intervals, which will allow us to place an upper bound on the time of extinction.