Estimating phenological trends using site occupancy models

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Introduction

Much of what we know about changes in phenology is based on observational data, and mostly on first observation dates. These, however, are influenced by several factors like observation effort, detection probability or the size of the studied population.
We developed a model that is able to estimate unbiased mean spring arrival dates by accounting for such factors.

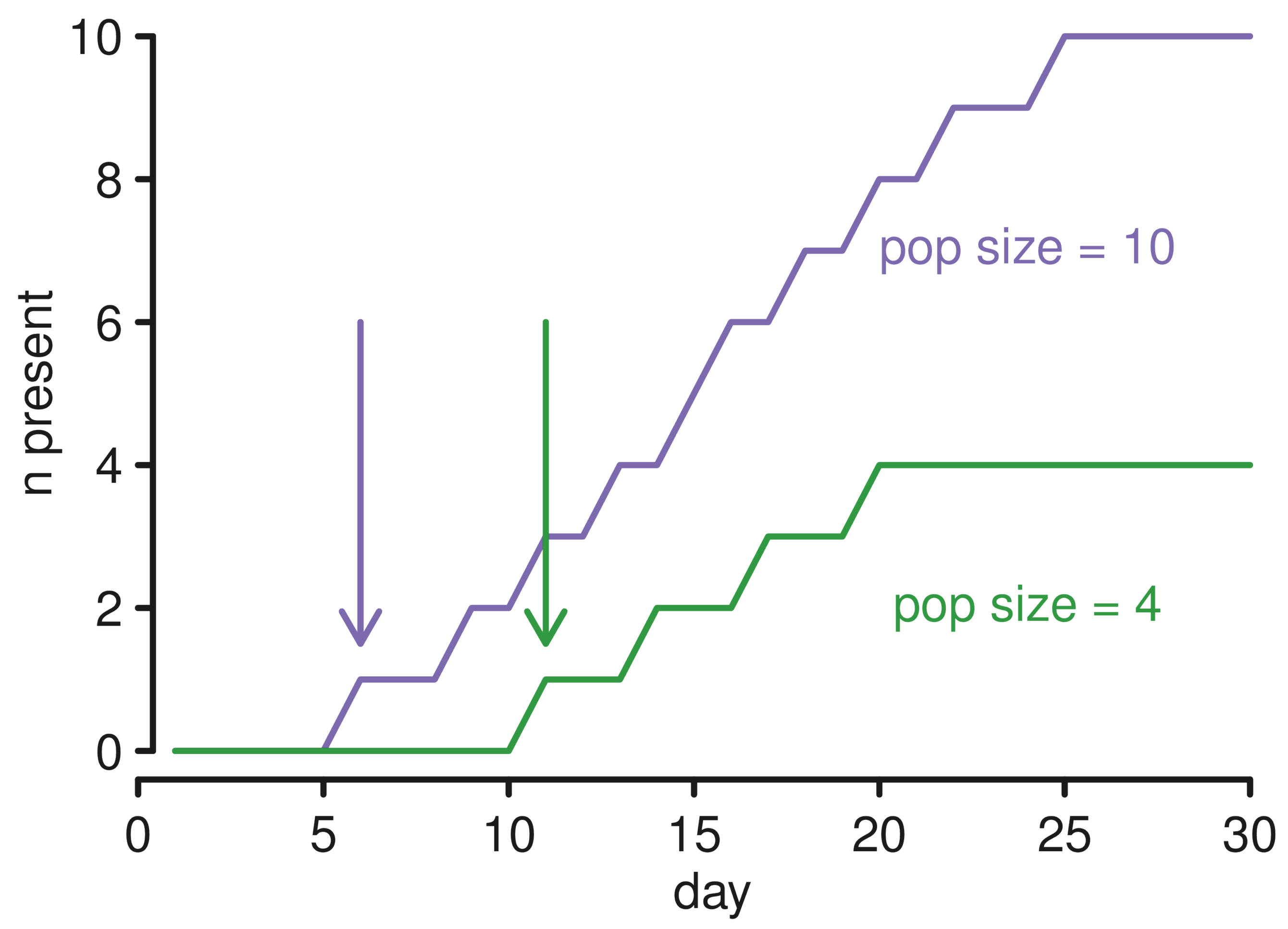

Figure 1: At the same mean arrival date, first arrival date is earlier in larger populations. The arrows point at the first arrival date.

Arrival site occupancy model

Based on the concepts of site-occupancy models, we developed a new method for estimating phenological events like spring appearance. This model provided precise estimates for mean spring arrival dates that were not influenced by changes in detection probability (see below) or population sizes (not shown).

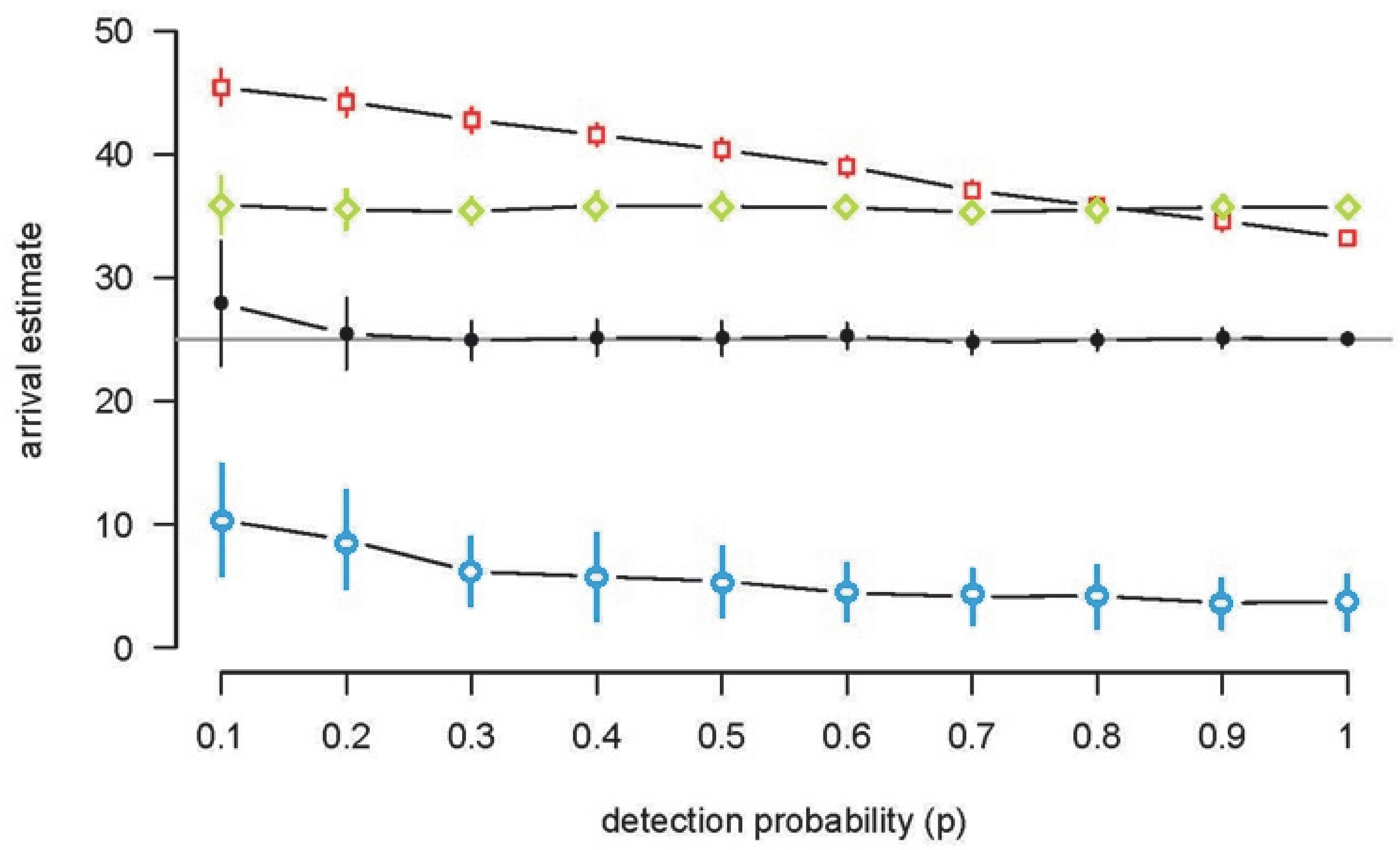

Figure 2: Comparison of first observation dates (blue), mean dates of all first observations from all sites (red), the date when 20% of all observations within the whole study are made (olive) and the estimates of our model (black) at different detection probabilities. In this simulation study, true mean arrival date was set as day 25.

Case study

The model was extended to analyze multi-year data sets and was applied to observational data.

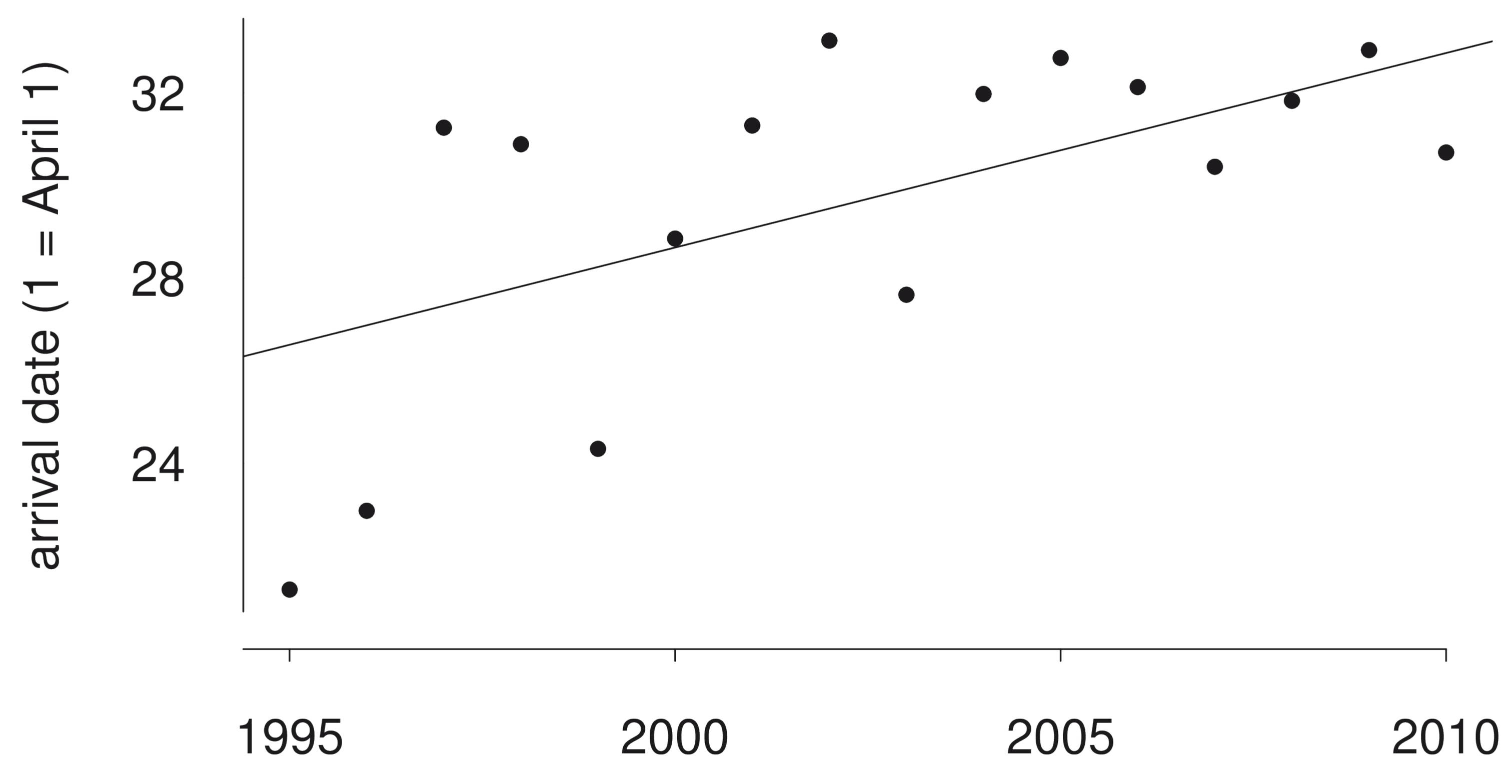

Figure 3: Estimated mean arrival dates in the garden warbler *Sylvia borin*. Data are from the long-term biodiversity monitoring program in Canton Aargau.

Based on our model, we found a significant shift towards a later mean arrival date in the garden warbler. This is in contrast to estimates based on first observation dates that did not show significant shifts of arrival over the years.

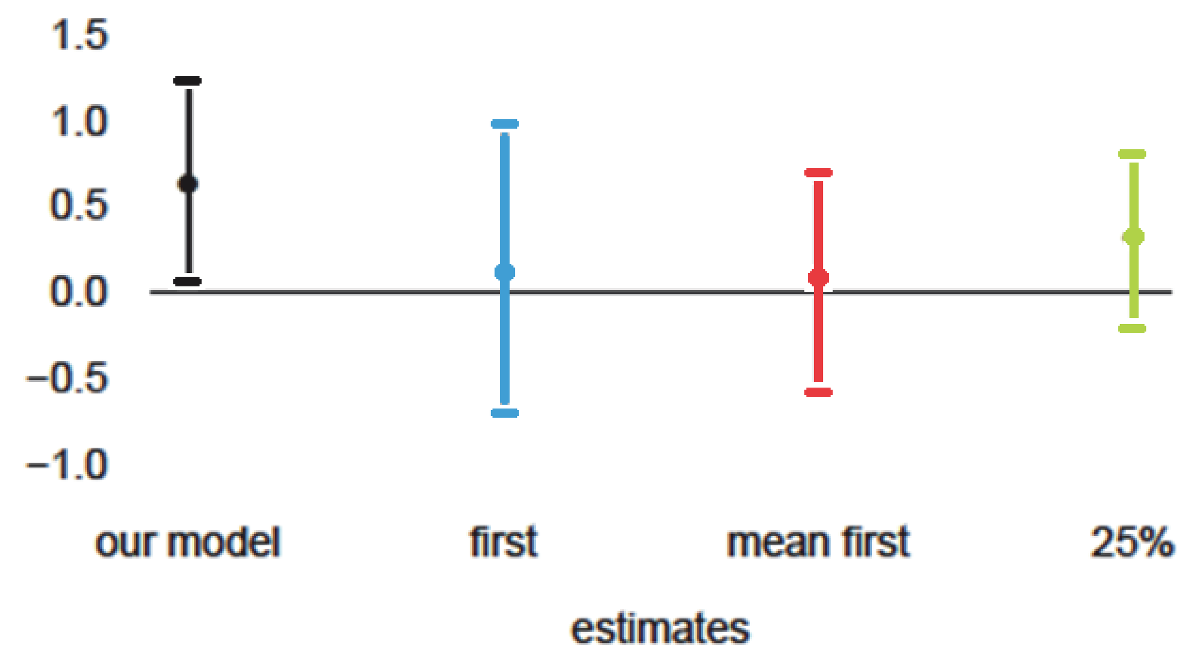

Figure 4: Estimated annual changes in arrival dates (means ±95% credible intervals) of garden warblers based on our model and on first observation dates.

Summary

First observation dates were not a reliable measure for tracking phenological changes because they showed to be influenced by several factors like population size and density or detection probability. In general, first observation dates do not provide information about the mean date of a phenological event.
Our model was able to account for changes in site occupancy and detection probability and provided estimates for the mean and the standard deviation of a phenological event.
Due to these features, our model could help in improving inferences on phenological changes based on observational data.

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