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A method for deriving time-variable avian re-nesting probability functions for use in seasonal productivity models

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The demographic parameters productivity, survival and migration ultimately determine local avian population trends. Their measurement is essential in bird conservation, for diagnosing proximate causes of population declines and for testing responses to management. It is ultimately seasonal productivity (productivity-per-female-per-season) that is required for demographic simulation or quantification of individual fitness.

However, measuring seasonal productivity is difficult in multi-brooded species without labour-intensive studies of marked birds. Dynamic models have been developed that do not require knowledge of the number of attempts made, but they have often had to use simplified re-nesting probability (φ_R) step-functions instead of more biologically intuitive time-variable functions. This has implications for how models simulate inter-individual variation in productivity, the relative contributions of early/late nests and re-nesting compensation.

For Blackbird *Turdus merula*, Chaffinch *Fringilla coelebs* and Yellowhammer *Emberiza citrinella* we demonstrate a modelling approach to derive time-variable φ_R functions where not all attempts can be located and females are unmarked. For Yellowhammer we test their performance (relative to simpler step-functions) within a dynamic simulation model.

Derived φ_R functions approximated reverse sigmoid shapes, matching expectations. Specified with the time-variable function, the simulation model better matched observed seasonal distribution of first egg-dates. In all outputs (productivity, attempts and season length) time-variable functions allowed for intermediate inter-individual variation compared with the step-functions.

The φ_R function used had implications for the strength and form of re-nesting compensation specified by the model, being linear using a time-variable function and non-linear using step-functions.

The method demonstrated is less resource-intensive than continuous monitoring of marked birds and thus potentially increases the availability of time-variable φ_R functions to researchers. Although not proven superior in estimating productivity, they widen the functionality of dynamic seasonal productivity models and thus provide an additional tool for demography studies in multi-brooded species.