Quantifying the limits to population forecasts

An example using the Yellowstone bison population

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MAIN GOALS

1. Fit Bayesian state-space model for bison population dynamics with an environmental covariate
2. Compare out-of-sample forecasts with and without known environmental conditions
3. Partition forecast uncertainty into components

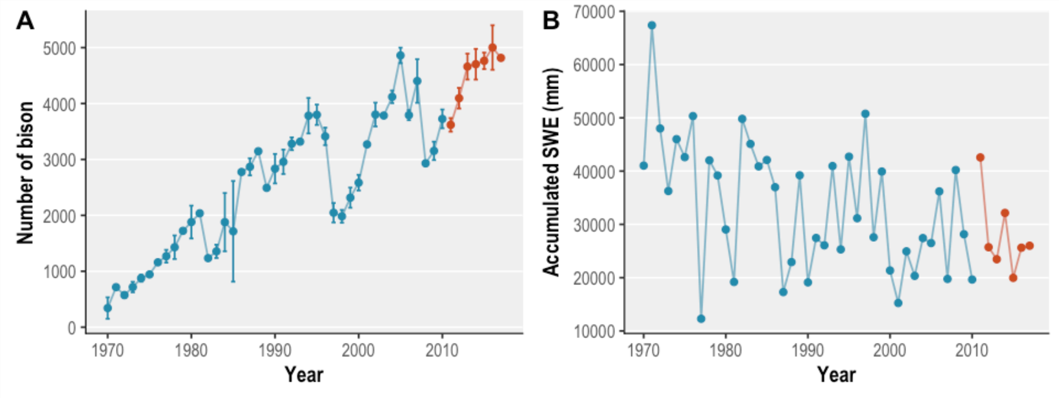
§ 1

The data

TIME SERIES OF BISON COUNTS (1970 - 2017)

Response Bison counts

Covariate Accumulated snow water equilivalent (West Yellowston SNOTEL)



training data · validation data

§ 2

The model

GOMPERTZ POPULATION GROWTH

$$\log\left(z_{(t)}\right) \sim \text{Normal}\left(\log\left(z_{(t-1)}\right) + r + b_0 \log\left(z_{(t-1)}\right) + b_1 x_{(t)}, \sigma^2_{\text{p}}\right)$$

z_t	latent population abundance in year t
r	per capita growth rate
b_0	density dependence
b_1	effect of snow water equivalent
x_t	accumulated snow water equivalent in year t
$\sigma^2_{\mathbf{p}}$	process variance

Likelihood

$$y_{(t)} \sim \text{NB}\left(z_{(t)}, \kappa\right)$$

Full model

$$\left[\theta_{\text{p}}, \kappa, z_{(t)}, z_{(t-1)} \middle| y_{(t)}, x_{(t)}\right] \propto \prod_{t=2}^{58} \underbrace{\left[z_{(t)} \middle| \theta_{\text{p}}, z_{(t-1)}, x_{(t)}\right]}_{\text{process}} \prod_{t=1}^{48} \underbrace{\left[y_{(t)} \middle| \kappa, z_{(t)}\right]}_{\text{data}} \underbrace{\left[\theta_{\text{p}}, \kappa, z_{(t=1)}\right]}_{\text{parameters}}$$

Includes a strong prior on r based on Hobbs et al. 2015: $r \sim \text{Normal}(0.1, 0.02)$

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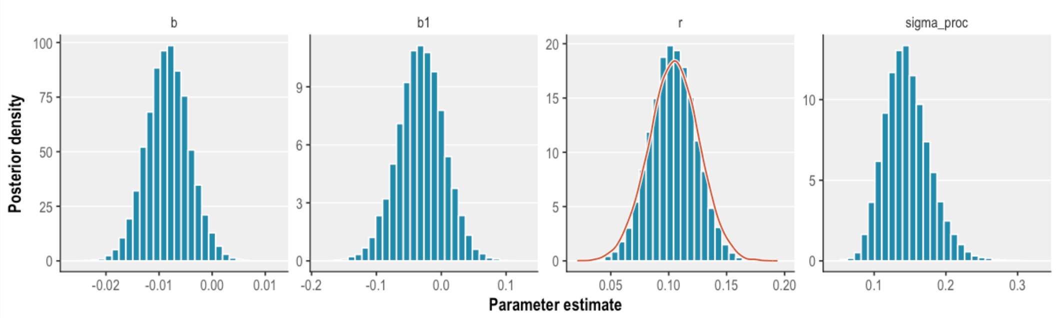
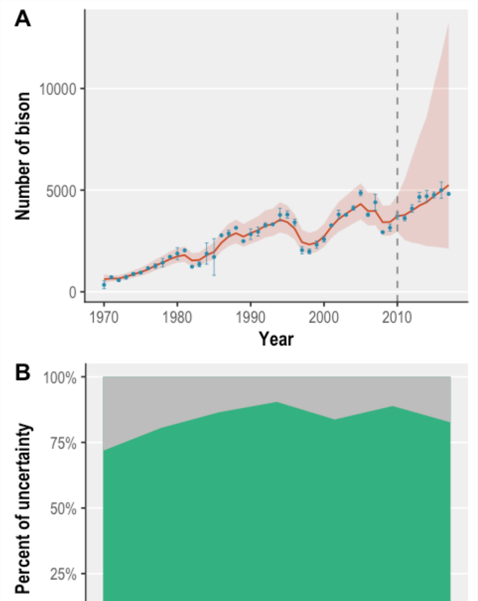
Results

POSTERIOR DISTRIBUTIONS OF PARAMETERS



Note: posterior distrbution of *r* totally informed by prior.

POSTERIOR PREDICTIONS, FORECASTS, AND FORECAST PARTITION



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Take home messages

TAKE HOME

1. Snow water equivalent effect is weak – right covariate?
2. Forecast uncertainty is large.
3. Forecast unceratinty dominated by (simulated) uncertainty of snow water equivalent