How predictable is extinction?

Forecasting species survival at million-year timescales

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Foundational assertion of conservation paleobiology

By studying the past,
we can better predict the future.

What are we predicting?

Extinction is hard to predict, but is important to conservation decisions.

Predicting extinction

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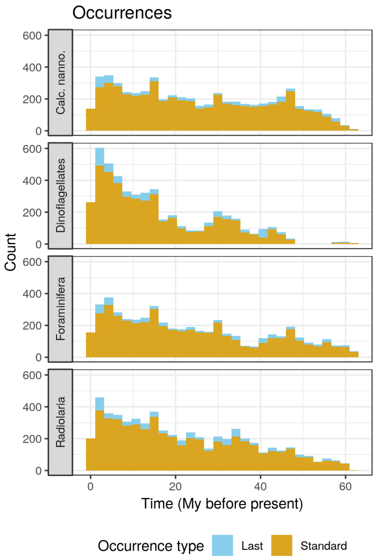
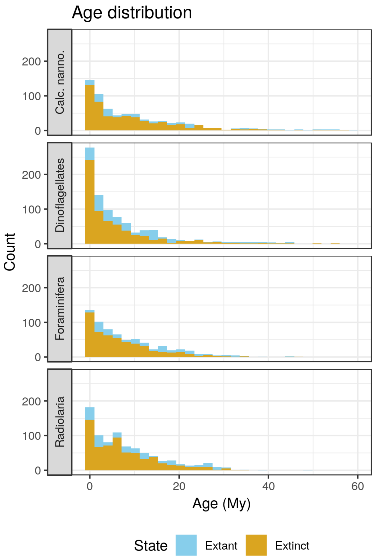
- A taxon's global geographic range can change over time.
- What happens to extinction risk as a taxon changes geographic range? How is extinction risk impacted if that taxon's global geographic range has recently increased or decreased?

Data being analyzed





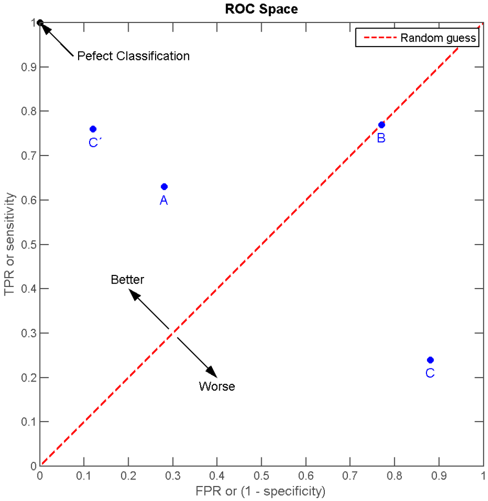
How we're analyzing the data

- Encoding the past
  - Change in geographic range between current observation and previous observation.
  - Average global temperature at time of previous observation (Mg/Ca isotope).
  - Age in millions of years at time of observation.
- Explore model adequacy using posterior predictive distribution.
- Estimate out-of-sample predictive performance using k-fold cross-validation.

Measuring performance: Reciever Operating Characteristic

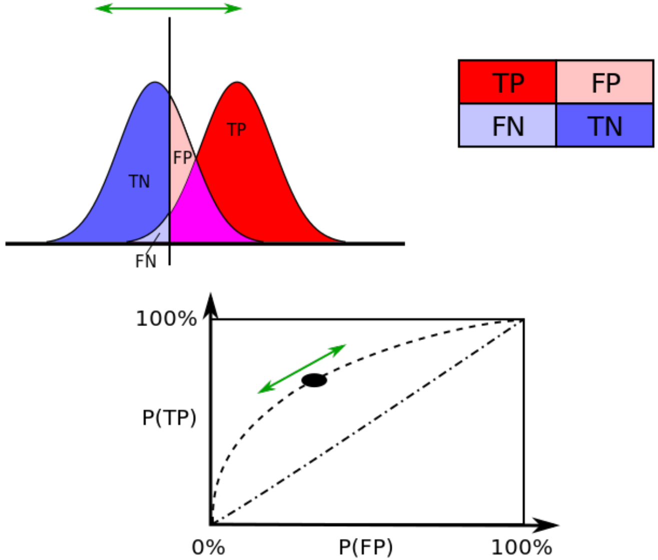
<table>
<tr><td colspan="2"></td><td colspan="2">Actual class</td></tr>
<tr><td colspan="2"></td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">Predicted class</td><td>1</td><td>TRUE POSITIVE</td><td>FALSE POSITIVE</td></tr>
<tr><td>0</td><td>FALSE NEGATIVE</td><td>TRUE NEGATIVE</td></tr>
</table>

Measuring performance: Reciever Operating Characteristic



(wikimedia)

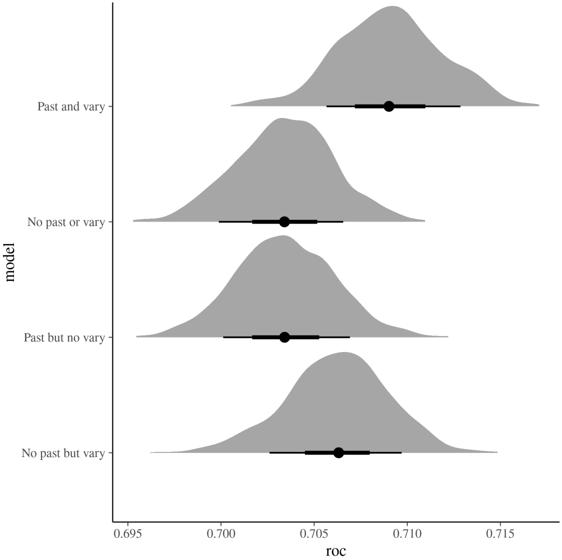
Measuring performance: Reciever Operating Characteristic



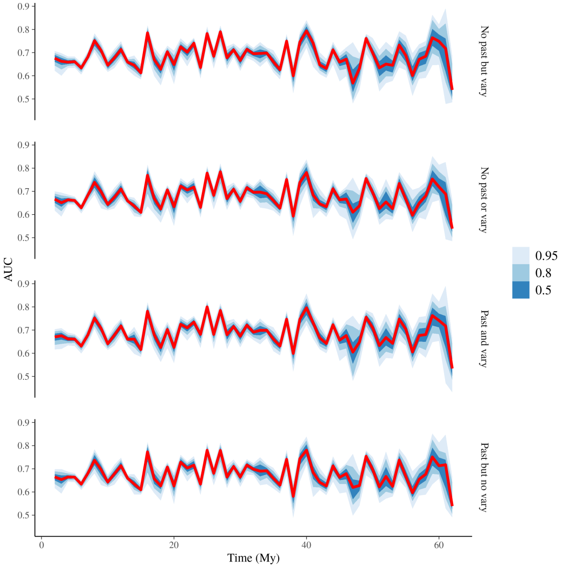
(wikimedia)

A conceptual model for predicting extinction

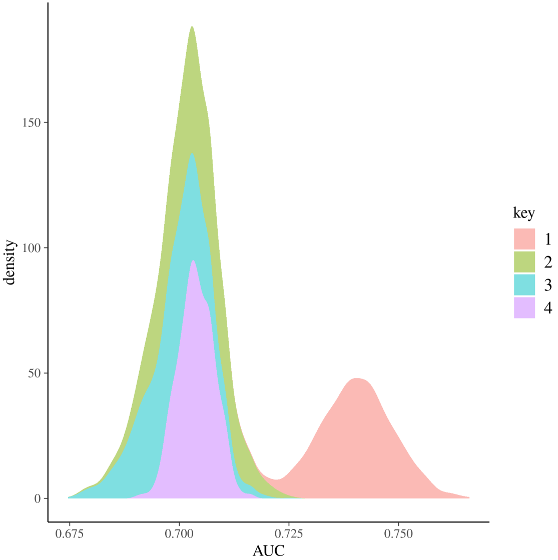
In-sample predictive performance, full dataset



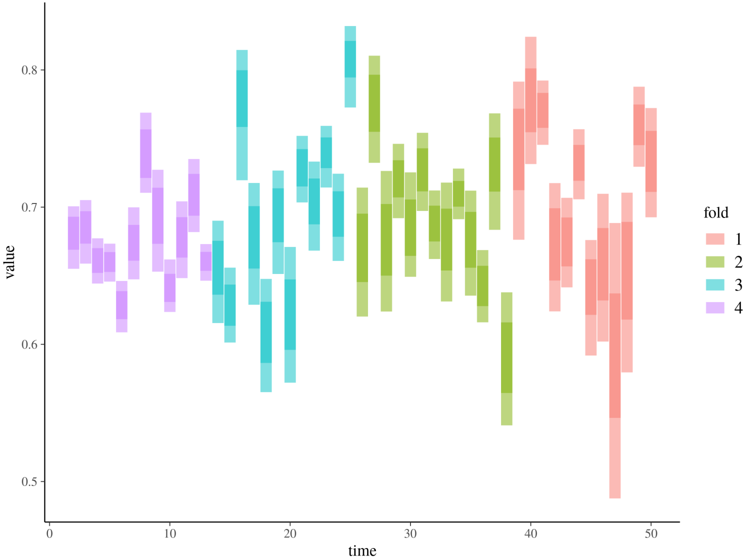
In-sample predictive performance, by time



Cross-validation results, full dataset



Cross-validation results, by time



Summary

Conclusions

Acknowledgements

A statistical model for predicting extinction

$$
\begin{aligned}
t_i &\sim \text{Bernoulli}(\Theta) \\
\Theta_i &= \text{logit}^{-1}(X_i B_{w[i],p[i]} + A_{d[i],p[i]}) \\
B_{w,p} &\sim MVN(\alpha_p, \Sigma_B) \\
\alpha_p &\sim MVN(\mu, \Sigma_\alpha) \\
A_{w,p} &\sim MVN(\delta_p, \Sigma_A) \\
\delta_p &\sim \mathrm{N}(0, \sigma_\delta) \\
\mu_d &\sim \begin{cases} N(0,10) & \text{if } d = 1 \\ N(-1,3) & \text{if } d = 2\ \Sigma_B \\ N(0,3) & \text{if } d > 2 \end{cases} && = diag(\tau_B)\Omega_B diag(\tau_B) \\
\Sigma_\alpha &= diag(\tau_\alpha)\Omega_\alpha diag(\tau_\alpha) \\
\Sigma_A &= diag(\tau_A)\Omega_A diag(\tau_A) \\
\tau_B &\sim C^+(5) \\
\tau_\alpha &\sim C^+(5)
\end{aligned}
$$

Effects of age on extinction risk, by phylum