Spatio-temporal Pattern and Eco-climatological Drivers of Striped Skunk Rabies

Kansas State Veterinary Diagnostic Laboratory
Manhattan, KS
Bayesian Spatiotemporal Pattern and Eco-climatological Drivers of Striped Skunk Rabies in the North Central Plains

Ram K. Raghavan\textsuperscript{1*}, Cathleen A. Hanlon\textsuperscript{2†}, Douglas G. Goodin\textsuperscript{3‡}, Rolan Davis\textsuperscript{1*}, Michael Moore\textsuperscript{1*}, Susan Moore\textsuperscript{1*}, Gary A. Anderson\textsuperscript{1*}

1 Kansas State Veterinary Diagnostic Laboratory and Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University, Manhattan, Kansas, United States of America, 2 Centers for Disease Control and Prevention, Atlanta, Georgia, United States of America, 3 Department of Geography, College of Arts and Sciences, Kansas State University, Manhattan, Kansas, United States of America

* These authors contributed equally to this work.
† CAH, DGG, and GAA also contributed equally to this work.
‡ rkraghavan@vet.k-state.edu
• Rabies
  • Oldest known zoonosis
  • Continues to kill people throughout the world
  • In N. America, it is mostly a wildlife disease
    • Mostly circulated by Carnivora and Chiroptera
    • All Skunks are susceptible but stripped skunks are most commonly reported
Distribution
• Retrospective case-control design
• Case reports from January 2007 – December 2013
  • 1027 tests
  • 705 negative/318 positive
  • 33 unsuitable for testing
• Address information from submission forms
  • Urban vs. rural
• Disease ecology influenced by environment and climate
• Physical environment
  • Land cover/land use
  • Land cover fragmentation
• Climate
  • Land surface temperature
  • Diurnal temperature range
  • Humidity
\[
\log[\pi_{ij}] = \beta_0 + \beta_{ij} v_{k_{ij}}
\]

\[
\pi_{ij} = p(y_i = 1 | x_i) \quad x_{ij} = (x_{ij1}, \ldots, x_{im})
\]

\[
\log\text{it} \left[ \pi_{ij} = \log \left[ \frac{\pi_{ij}}{1 - \pi_{ij}} \right] = x_i \beta \right]
\]
\[ \log(\pi_{ij}) = \beta_0 + u_i + v_i + \gamma_j \]

\[ u_i \sim CAR \]

\[ v_i \sim Normal(0, \sigma_v^2) \]

\[ \gamma_j \sim N(\gamma_{j-1}, \tau_\gamma^{-1}) \]
\[
\log(\pi_{ij}) = \beta_0 + u_i + v_i + \gamma_j + \psi_{ij}
\]

\[
\psi_{ij} \sim (\psi_{ij-1} \tau_\psi)
\]
<table>
<thead>
<tr>
<th>Model</th>
<th>$\bar{D}$</th>
<th>$P_D$</th>
<th>DIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1a)</td>
<td>1320</td>
<td>81</td>
<td>1401</td>
</tr>
<tr>
<td>(1b)</td>
<td>1345</td>
<td>114</td>
<td>1459</td>
</tr>
<tr>
<td>Covariate$^e$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td>952</td>
<td>32</td>
<td>984</td>
</tr>
</tbody>
</table>

$\bar{D}$ = posterior mean deviance, calculated as $\bar{D} = E[D]$, where $D = -2\log p(y|\theta)$.

$P_D$ = Posterior mean deviance—deviance of posterior means, calculated as $P_D = E_{\theta^y}[D] - D(E_{\theta^y}[\theta])$.

$DIC$ = Deviance information criterion, analogous to the frequentist AIC estimate and estimated as $DIC = D(\tilde{\theta}) + 2P_D$.

$^e$Several covariate models (which also included random effect terms) were fitted starting with a model that included all covariates that were screened in the univariate procedure with a liberal $p \leq 0.2$, followed by the removal of one covariate at a time from the Bayesian hierarchical models. The removal of % grassland area, minimum land surface temperature and an interaction term, ‘diurnal temperature range x % mixed forest area’ one at a time, in that order resulted in models with $DIC$ values of 1261, 1014, and 1008. To the final covariate model, a random effect space-time term, $\Psi_y$ was inserted, which resulted in a $DIC$ value of 1023, indicating poor performance. Other previously removed covariates did not re-enter the final covariate model.

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Partial model (1a)</th>
<th>Partial model (1b)</th>
<th>Covariate model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_0$</td>
<td>$0.35 \pm 0.04$</td>
<td>$0.33 \pm 0.04$</td>
<td>$0.28 \pm 0.03$</td>
</tr>
<tr>
<td>$u_i$</td>
<td>$0.04 \pm 0.00$</td>
<td>$0.06 \pm 0.02$</td>
<td>$0.02 \pm 0.01$</td>
</tr>
<tr>
<td>$v_i$</td>
<td>$0.18 \pm 0.02$</td>
<td>$0.11 \pm 0.01$</td>
<td>$0.08 \pm 0.02$</td>
</tr>
<tr>
<td>$y_j$</td>
<td>$0.23 \pm 0.05$</td>
<td>$0.20 \pm 0.05$</td>
<td>$0.21 \pm 0.05$</td>
</tr>
<tr>
<td>$\Psi_{ij}$</td>
<td>-</td>
<td>$-0.03 \pm 0.05$</td>
<td>-</td>
</tr>
</tbody>
</table>

**Random effect terms (Mean ± SD):**

Mean and standard deviation correspond to the posterior estimates for the hyperparameters $\tau_u, \tau_v, \tau_y$, and $\tau_q$ in the three Bayesian models present above.

**Fixed effect covariates (Odds ratio, 95% Credible Intervals):**

- $\beta_1$ (% developed—low intensity areas) - $3.41 \ (2.01, 3.83)$
- $\beta_2$ [Total edge contrast index (fragmentation)] - $1.70 \ (1.26, 2.81)$
- $\beta_3$ (Diurnal temperature range) - $0.54 \ (0.27, 0.91)$

The odds ratio and credible intervals correspond to the median of the posterior predictive distributions of the covariate model.

$\beta_0$ is intercept in all models, representing positive striped skunk rabies infection in all locations in all years, and $u_i$ and are $v_i$ random terms accounting for spatially structured variation in striped skunk rabies infection and unstructured heterogeneity in the data, respectively. $y_j$ and $\Psi_{ij}$ terms represent non-parametric time trend and spatio-temporal interactions, respectively. Information on the choice of priors for these terms are provided in the text.
• Disease levels are stable
• Significant environmental factors behind disease prevalence
• Passive surveillance can be useful
• Thank you!