

Spatial Auto-Logistic Regression Modeling of South Central Skunk Variant Rabies in the Four Corners States

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Distribution of Terrestrial Rabies Virus Variants, United States, 2008 to 2015

Health department warns of rabid skunks in Durango

Video shows sickened animal near 11th Street and East Second Avenue

November 2017

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Variant Distance to Bordering States (Miles)

Skunk Rabies Variant

Specimen State	Distance to Bordering State			
	Arizona	Colorado	New Mexico	Utah
AZ		326.1	18.3	310.1
CO	259.6		20.1	188.0
NM	245.7	6.6		246.6
UT	--	--	--	

Fox Rabies Variant

Specimen State	Distance to Bordering State			
	Arizona	Colorado	New Mexico	Utah
AZ	--	201.1	5.5	141.4
CO	--	--	--	--
NM	104.4	200.8	--	225.4
UT	--	--	--	--

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Spatial Auto-logistic Regression Model Steps

- Geocoding, cleaning of case data
- Literature review
- Covariate Data Mining, Cleaning & Descriptives
- Correlation and Variance Inflation Assessment
- Non-spatial logistic Regression Modeling Building
- Spatial Autocorrelation Assessment
- Spatial (Autologistic) Regression modeling
- Boot Strapping and Model Confidence Intervals
- Output & Interpretation

esri ArcGIS R Studio

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RABV+ Specimens Locations, 2013-2017

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SCSK Specimens by State, 2013-2017

N= 435

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SCSK Specimens by Collection Month, 2013 - 2017

N= 435

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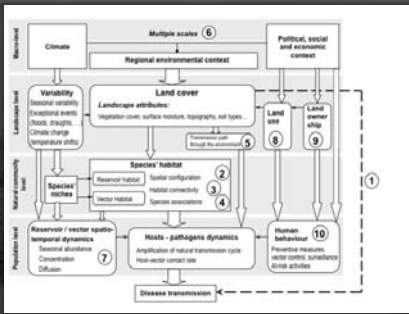
SCSK Specimens by Species, 2013-2017

- 81.5% Striped Skunks
- 7.6% Hooded, Hog-Nosed, E. & W. Spotted Skunk Species
- 4.4% Domestic Animals - Cats, Dogs, Horses, Cattle
- 4.1% Grey and Red Foxes
- 2.5% Other Wild Animals - Coyote, Raccoon

N= 435

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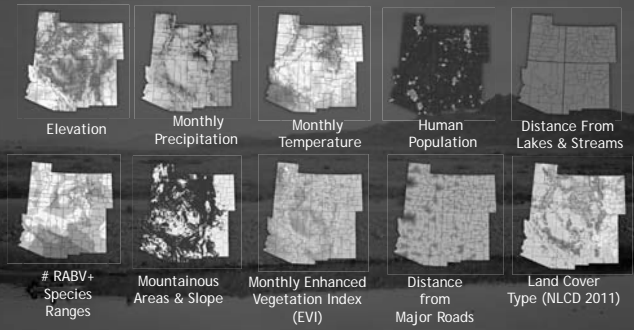
Landscape Epidemiology of Disease



Lambin et al. International Journal of Health Geographics 2010 9:54



Model Covariates Based on Literature



Model Covariate Correlations (Spearman)

	MTS	NLCD	DEM	SLOPE	SPECIES_1	ROADDIST	PRECIP	POP	EVI	WATERDIST	TEMP
MTS	1	0.24	0.51	0.23	0.13	0.11	0.11	0.25	0.25	0.25	0.25
NLCD		1	0.43	0.27	0.49	0.19	0.29	0.29	0.29	0.29	0.29
DEM			1	0.43	0.27	0.49	0.19	0.29	0.29	0.29	0.29
SLOPE				1	0.43	0.27	0.49	0.19	0.29	0.29	0.29
SPECIES_1					1	0.43	0.27	0.49	0.19	0.29	0.29
ROADDIST						1	0.43	0.27	0.49	0.19	0.29
PRECIP							1	0.43	0.27	0.49	0.19
POP								1	0.43	0.27	0.49
EVI									1	0.43	0.27
WATERDIST										1	0.43
TEMP											1

- Elevation (DEM) and Temperature are highly inversely correlated (-0.81)
- # Species and Temperature are inversely correlated (-0.58)
- Slope and Mountains are positively correlated (0.5) (only???)
- Precipitation and Vegetation Index (EVI) are somewhat positively correlated (0.54)



Model Covariates: Variance Inflation Factor (VIF)

$$VIF_i = \frac{1}{1 - R_i^2}$$

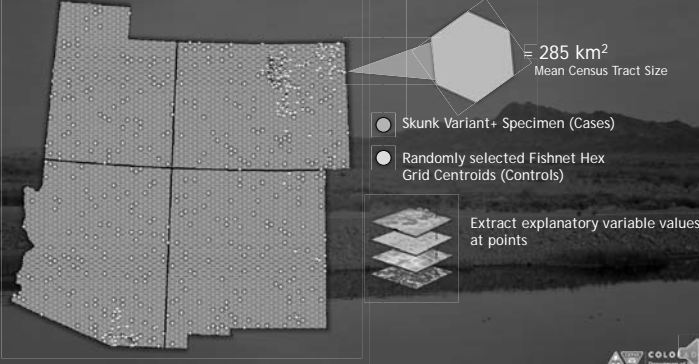
Variable	VIF
Temperature	11.5
Elevation	9.6
NLCD	8.1
Species	5.6
Precipitation	2.4
Slope	2.3
Mountain Areas	2.3
EVI	1.8
Human Population	1.3
Road Distance	1.1
Water Distance	1.1
Road Distance	1.1

- Variance Inflation Factor (VIF) is a test for multicollinearity
- It estimates how the variance of a regression coefficient is inflated due to multicollinearity in the model.
- Rough subjective guide:
 - 1: not correlated
 - 1-5: somewhat correlated
 - 5-10: highly correlated
 - Above 10: Do Not Use
- Omitting Temp, Elevation, & NLCD out of caution

Omit

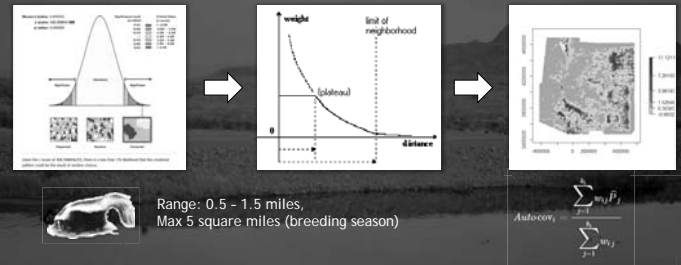


Hexagon* Fishnet Grid Sampling Schema



Modeling of Spatial Relationships

Inverse Distance Weighting with 5 mile neighborhood threshold



SCSK Stepwise Bootstrapped SAR Results

Variable	Estimate	Std. Error	Z-value	P value
(Intercept)	-11.2661	1.310747	-8.595	<0.0001
Enhanced Vegetation Index	0.002342	0.000333	7.037	<0.0001
Dist. From Roads (meters)	-0.00014	0.000023	-5.908	<0.0001
No. RABV+ Species	0.677989	0.109112	6.214	<0.0001
Human Population (per person)	0.000121	0.0000368	3.272	<0.01
Mountainous (cat)	-0.67041	0.299421	-2.239	<0.05
Precipitation (mm)	0.004184	0.000955	4.383	<0.0001
Slope (%)	-0.25729	0.062597	-4.11	<0.001
Autocovariate (0-1)	1322.814	275.9775	4.793	<0.001

GOF Measure	Null Model	Non-Spat. Model	Spat. Model
AICC	1192.1	589.09	568.89
McFadden's Pseudo R2	0.0	0.52	0.54
Chi Square (χ ²)	---	571.09	550.89
ROC	0.5	0.94	0.94

Autocovariate is high due to the scale of unit, small sample size, and high clustering of RABV+ specimens



SCSK Stepwise Bootstrapped SAR Results

Variable	Odds	95% High	95% Low
No. RABV+ Species	1.97	1.60	2.46
Mountainous (cat)	0.51	0.28	0.92
Slope (%)	0.77	0.68	0.87

$$OR_x = e^{\beta}$$



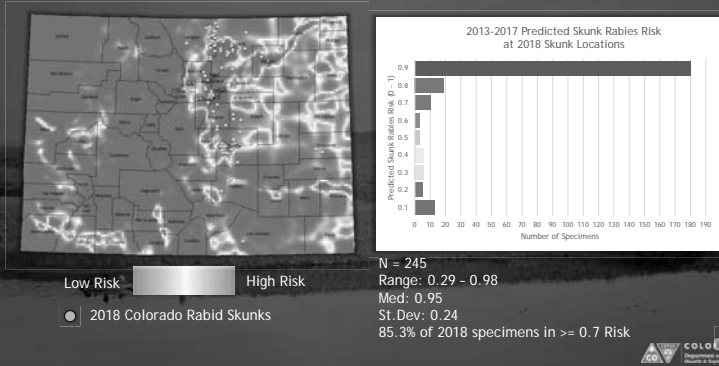
Skunk Variant Model Risk Results



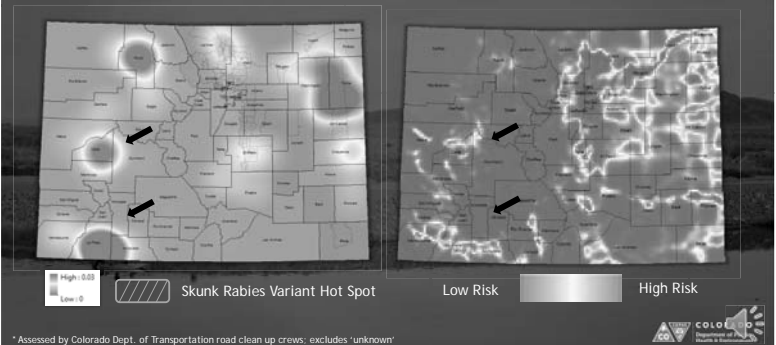
Nice Model...So What?

$$P_i(y_i = 1 | \beta_0, \beta_1, r) = \frac{\exp(\beta_0 + \beta_1 x_{1,i} + \dots + r \text{Auto cov}_i)}{1 + \exp(\beta_0 + \beta_1 x_{1,i} + \dots + r \text{Auto cov}_i)}$$

SCSK Model vs. Colorado SCSK Skunks (2018)



Skunk Roadkill Density* (CDOT) vs. SCSK Model



SCSK Model vs. Dog Vaccine Requirements



Improvements to Consider



- More years, greater sample size
- Higher case-control ratio (3:1? 4:1)
- Different explanatory variables
- Seasonality/years (Poisson)
- Bayesian modeling techniques
- Presence-Only Ecological modeling (MAXLIKE)
- Different sampling structure

QUESTIONS?

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THANK YOU!

Arizona Dept. of Health Services
New Mexico Dept. of Health
Utah Department of Health



Statue of the Goddess Mephitis, Roman Goddess of springs and noxious vapors, at Segino



Mephitis mephitis