Avian GIS Models Signal Human Risk for West Nile Virus in Mississippi

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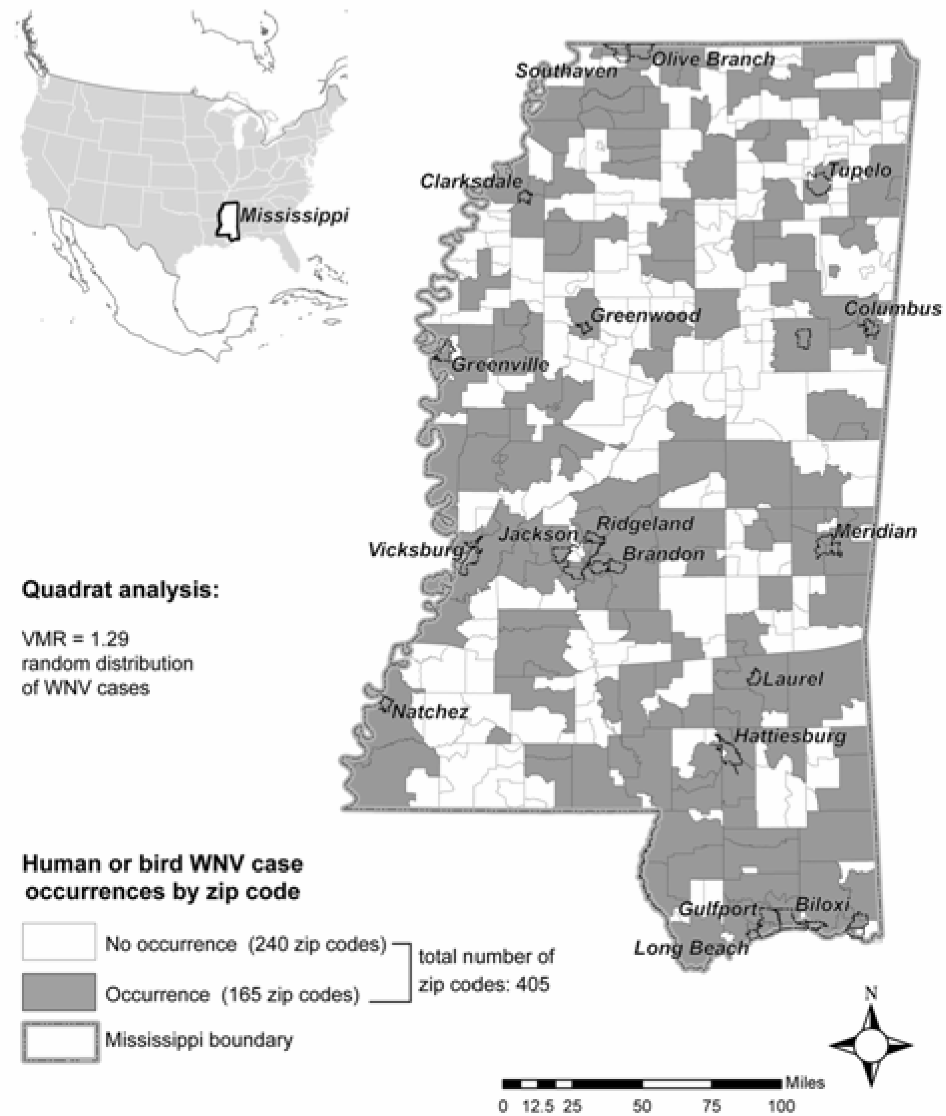
Goal:

Background

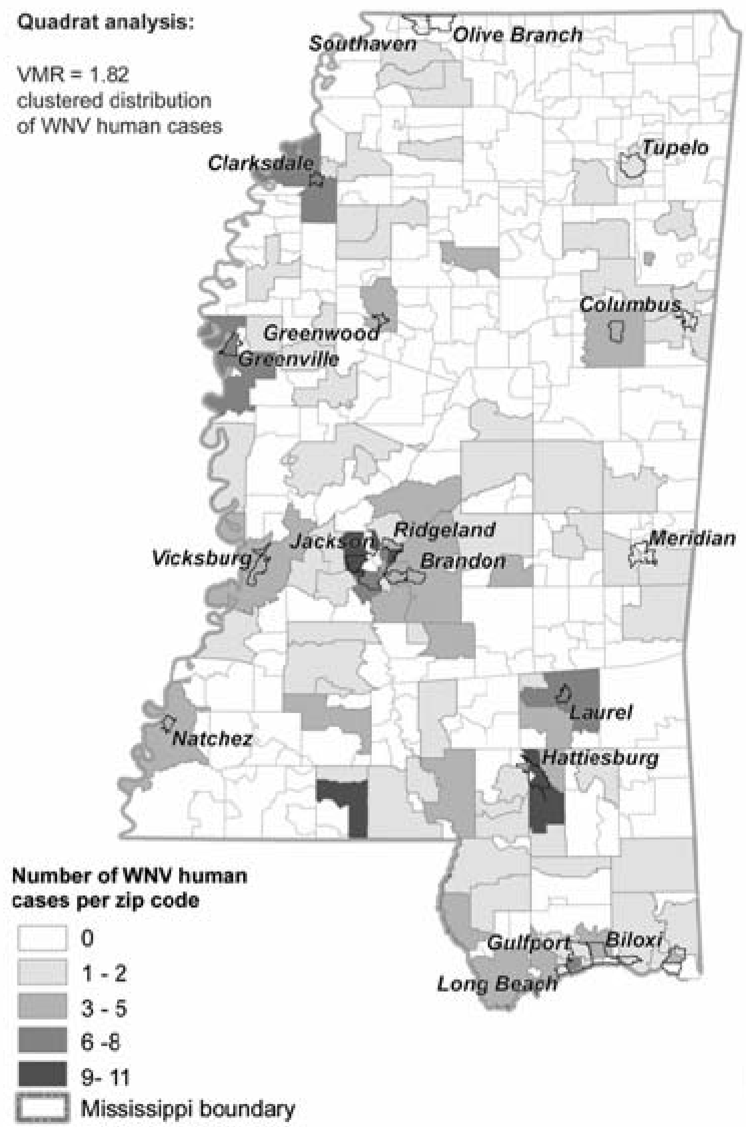
Estimate the importance of landscape variables as predictors of WNV infection in the state of Mississippi

- Analysis of avian and environmental data to model habitat suitability for mosquitoes that carry WNV
- Mosquito habitat suitability used as a surrogate for estimating potential risk of WNV infection for humans
- Analysis performed in raster environment
- Data on WNV bird and human infections are case occurrences by zip code
- Ecological test data are also summarized by zip code
- Statistical tests were used to determine predictive value of landscape variables for modeling statewide WNV risk

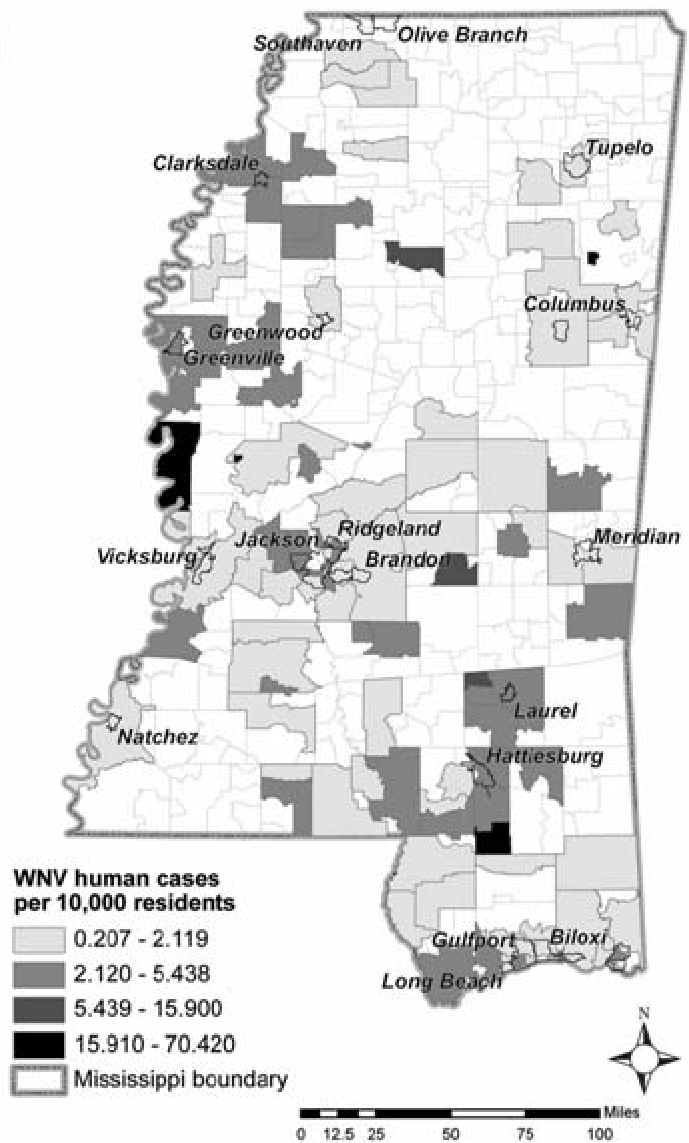


Study area context map; areas of WNV infections (combined human and bird data) in Mississippi in 2002 and 2003

Background



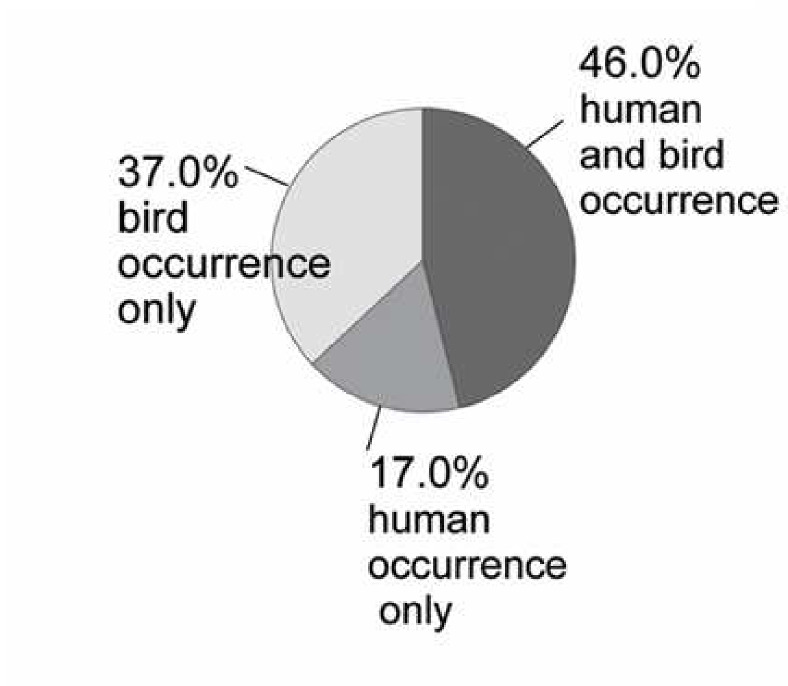
WNV human cases in 2002 and 2003 categorized by number of cases per zip code

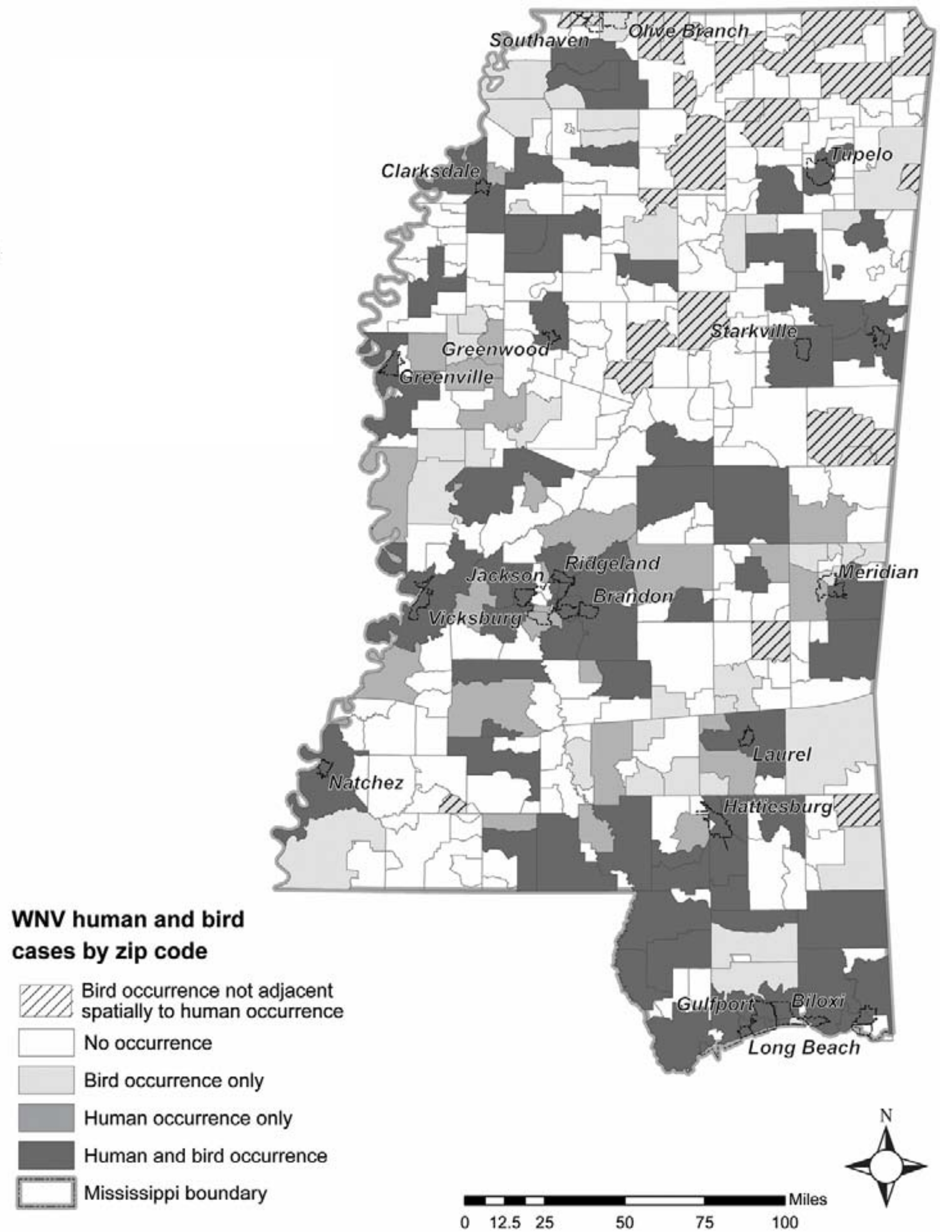


WNV human cases normalized by population (number of WNV cases per 10,000 residents)

Background

Areas of WNV infections





WNV infections in 2002 and 2003 categorized by the type of occurrence:

- bird occurrence only
- human occurrence only
- human and bird occurrence

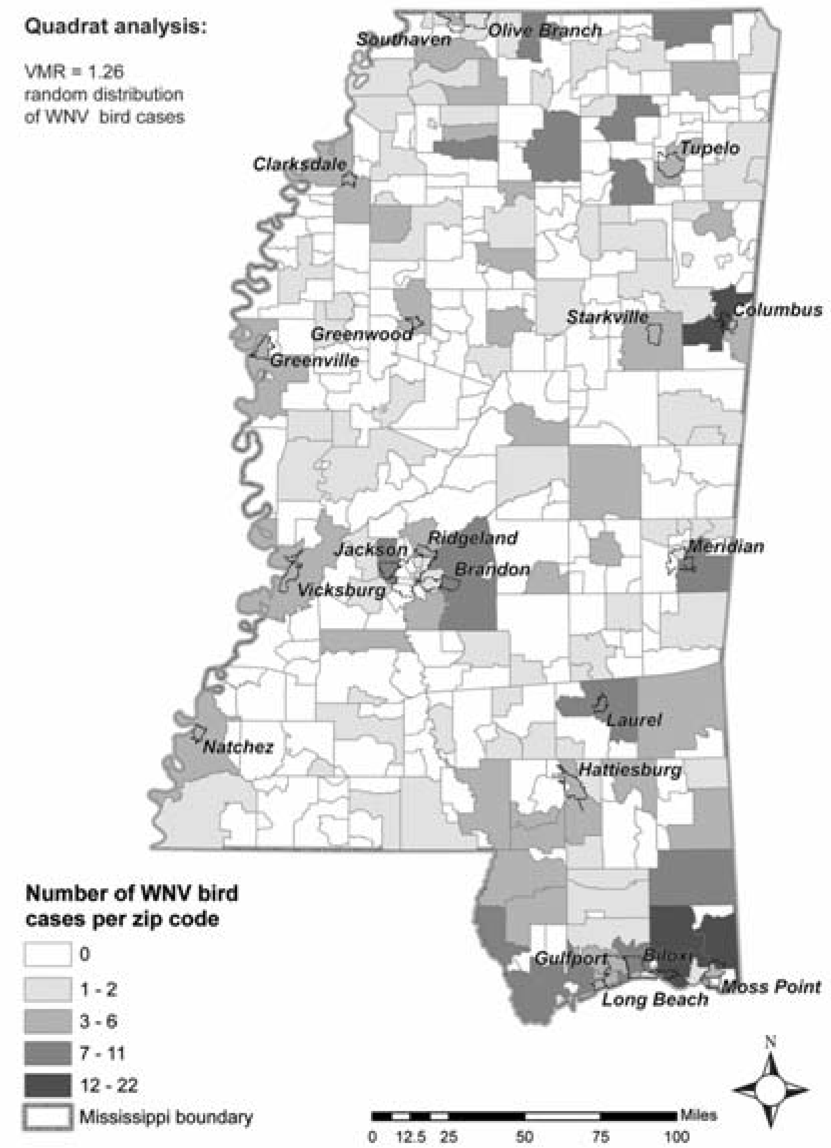
Study Significance

- Assessment of the WNV risk at a statewide scale (potential for optimization of mosquito spraying, allocation of educational materials, and sampling efforts)

- Unique use of environmental variables to identify areas ecologically capable of sustaining the virus (most researchers rely on dead bird reports or mosquito data)

- Variable significance and weights determined through a deterministic algorithmic approach with variable ranking assigned using statistical probability level

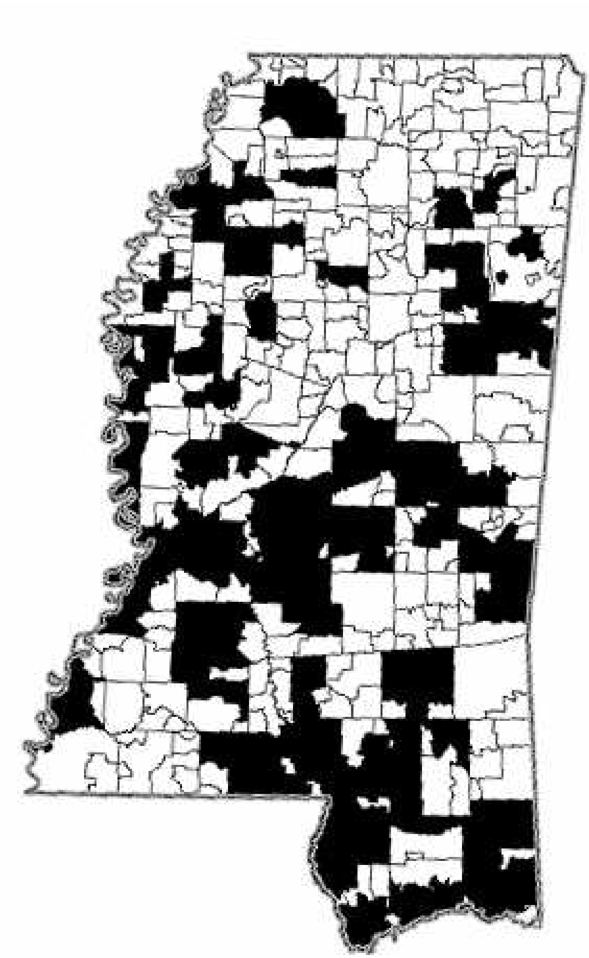
- Innovative way to construct risk predictions using raster-based GIS modeling



WNV bird cases in 2002 and 2003 categorized by number of cases per zip code

Models

Model I (based on human data)



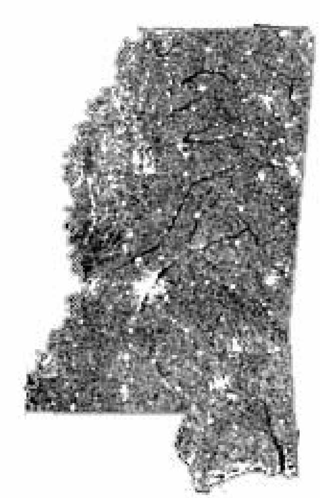
Model II (based on bird data)

Zip codes with human occurrence in 2002 and 2003
Zip codes with no human occurrence in 2002 and 2003

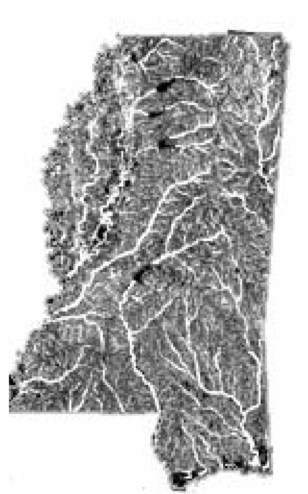
Zip codes with bird occurrence in 2002 and 2003
Zip codes with no bird occurrence in 2002 and 2003

Methods

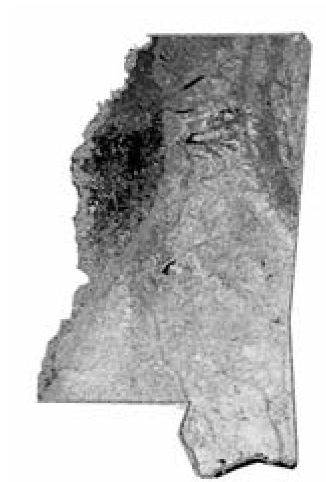
Variables



road density

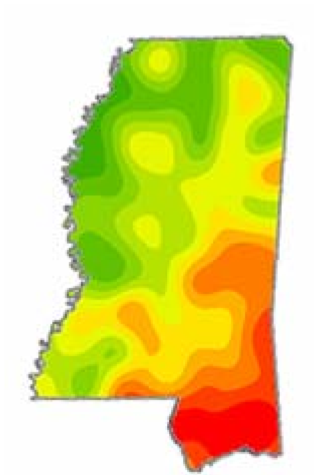


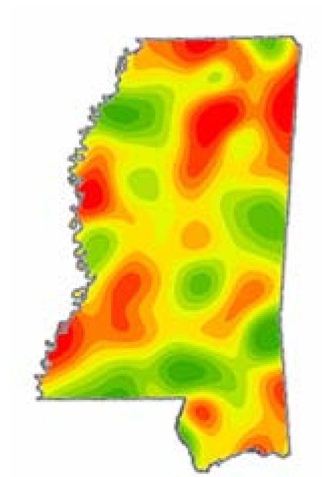
stream density



vegetation (NDVI)

slope





Seasonal Precipitation – Evaporation (P-E)
Summer 2003 Fall 2003

$$w_j = \frac{n - r_j + 1}{\sum (n - r_k + 1)}$$

Variable ranking/weights assignment

Where:

w_j **is normalized weight for the** j^{th} **criterion**

n **is the number of criteria under consideration (k = 1,2,…**n**)**

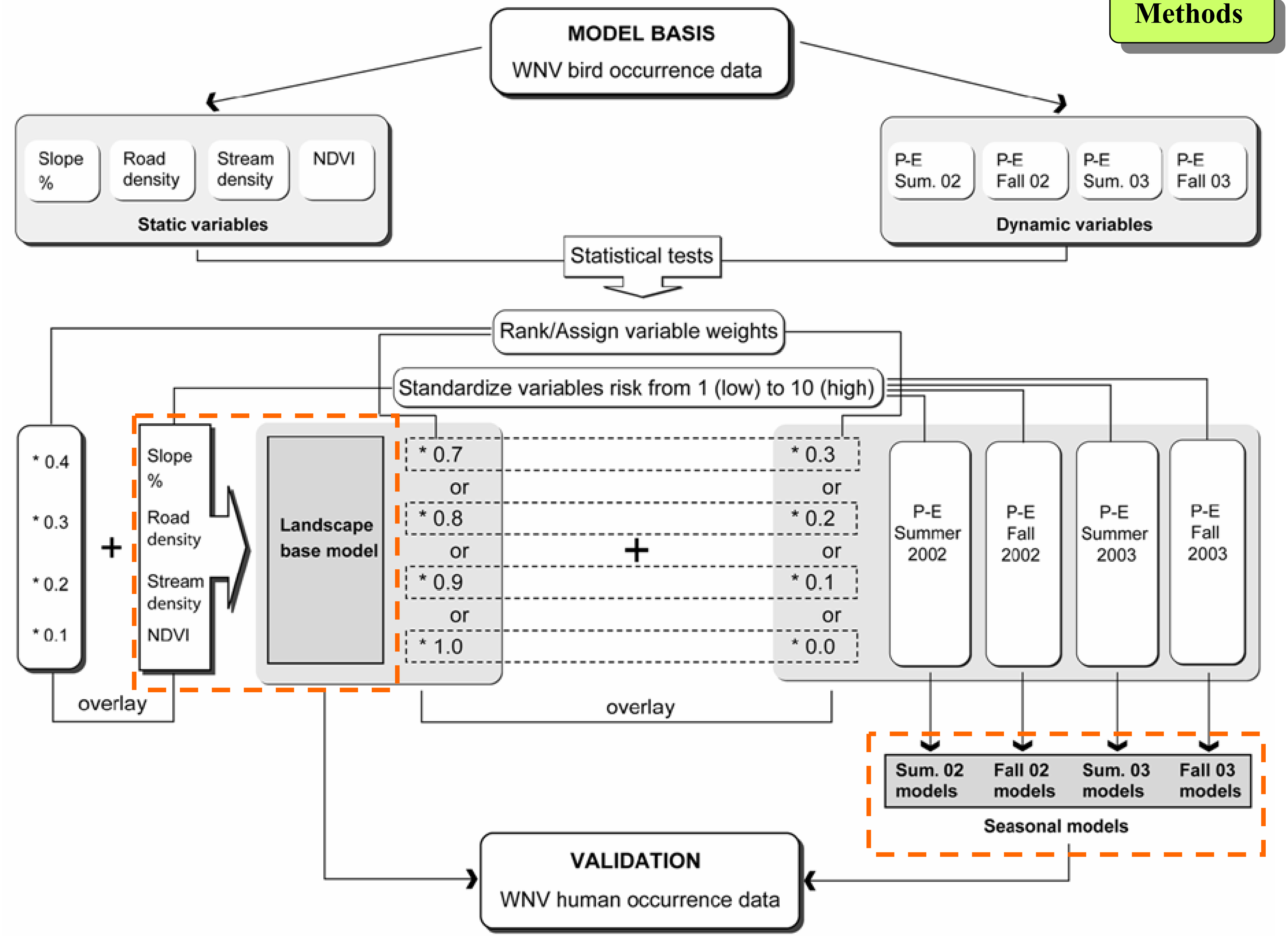
r_j **is the rank position of the criterion**

Methods

Summary of static variable testing, ranking and weight calculations

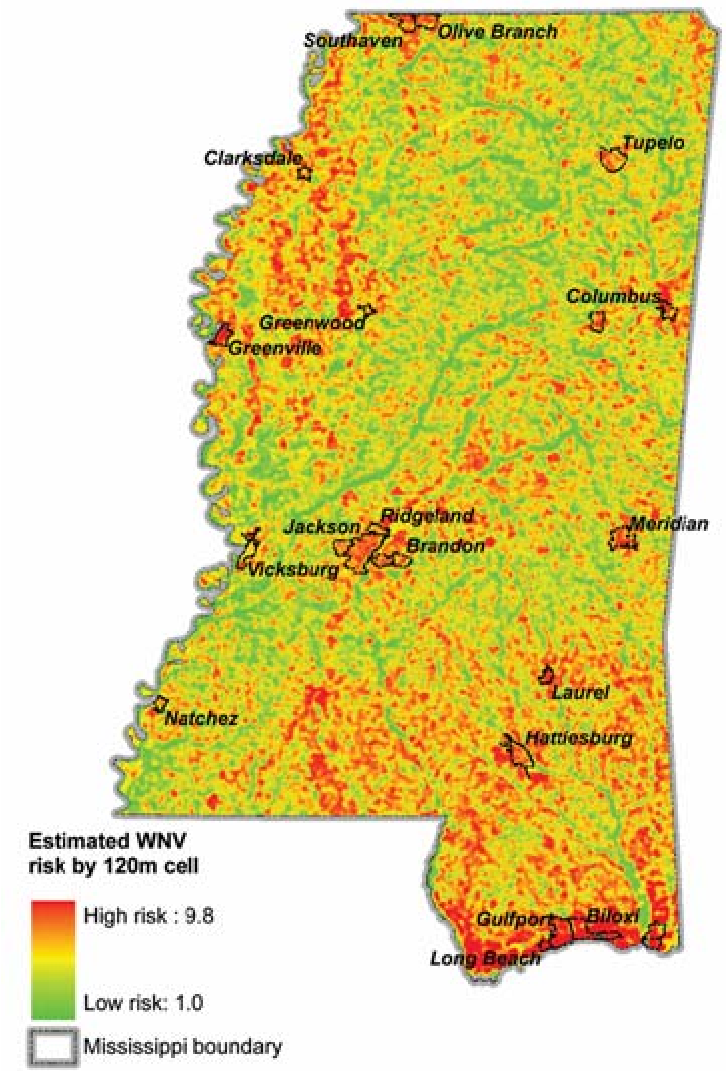
Variable	Relation to ecology of WNV vector mosquitoes	Mean for zip codes with		T-test significance (p-value)	WNV risk level 1- low risk 10 - high risk	Variable	
		WNV bird occurrence	no WNV bird occurrence			Rank	Weight
Road density	Breeding sites along roads	1.7568	1.1550	.000	High rd. 10 Low rd. 1	1	0.4
Stream density	Low stream density correlated with favorable habitat	1.1200	1.1868	.010	High sd. 1 Low sd. 10	2	0.3
Slope percent	Aspect of water outflow rate	7.1416	7.9886	.028	Gentle sl. 10 Steep sl. 1	3	0.2
NDVI vegetati on	Vegetation as resting and breeding sites	164.6797	160.9131	.251	**High NDVI 10** **Low NDVI 1**	4	0.1

Methods

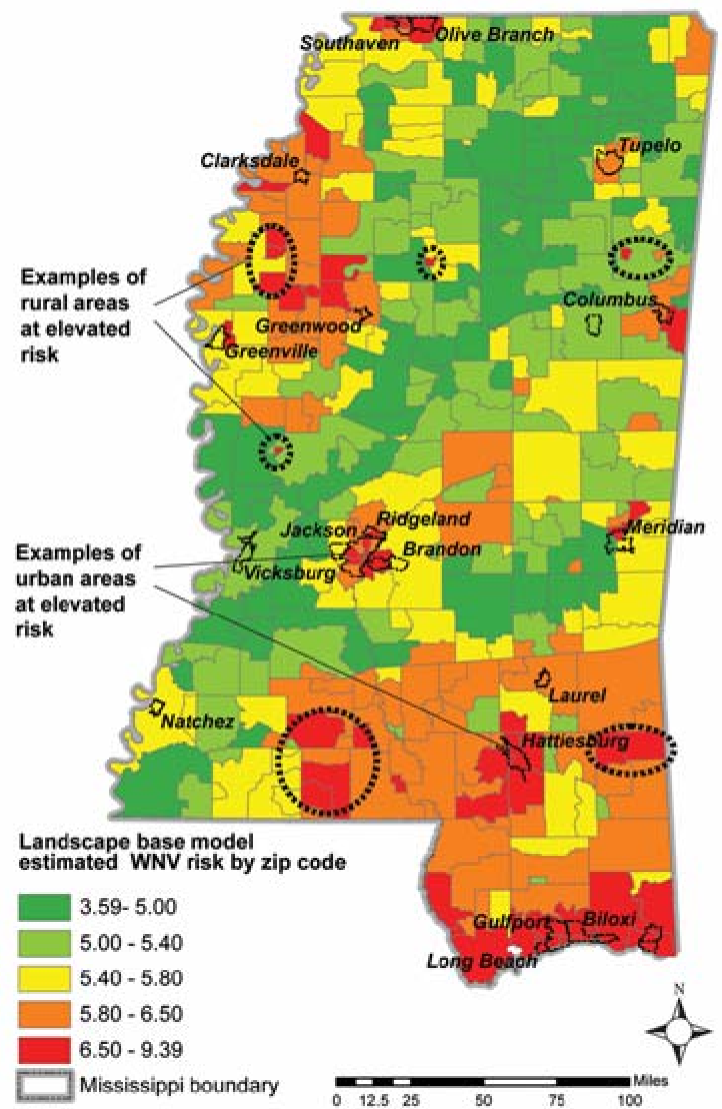


MODEL BASIS
WNV bird occurrence data
Slope %
Road density
Stream density
NDVI
Static variables
P-E Sum. 02
P-E Fall 02
P-E Sum. 03
P-E Fall 03
Dynamic variables
Statistical tests
Rank/Assign variable weights
Standardize variables risk from 1 (low) to 10 (high)
* 0.4
* 0.3
* 0.2
* 0.1
+
Slope %
Road density
Stream density
NDVI
overlay
Landscape base model
* 0.7
or
* 0.8
or
* 0.9
or
* 1.0
+
* 0.3
or
* 0.2
or
* 0.1
or
* 0.0
P-E Summer 2002
P-E Fall 2002
P-E Summer 2003
P-E Fall 2003
overlay
Sum. 02 models
Fall 02 models
Sum. 03 models
Fall 03 models
Seasonal models
VALIDATION
WNV human occurrence data

Results of landscape base model



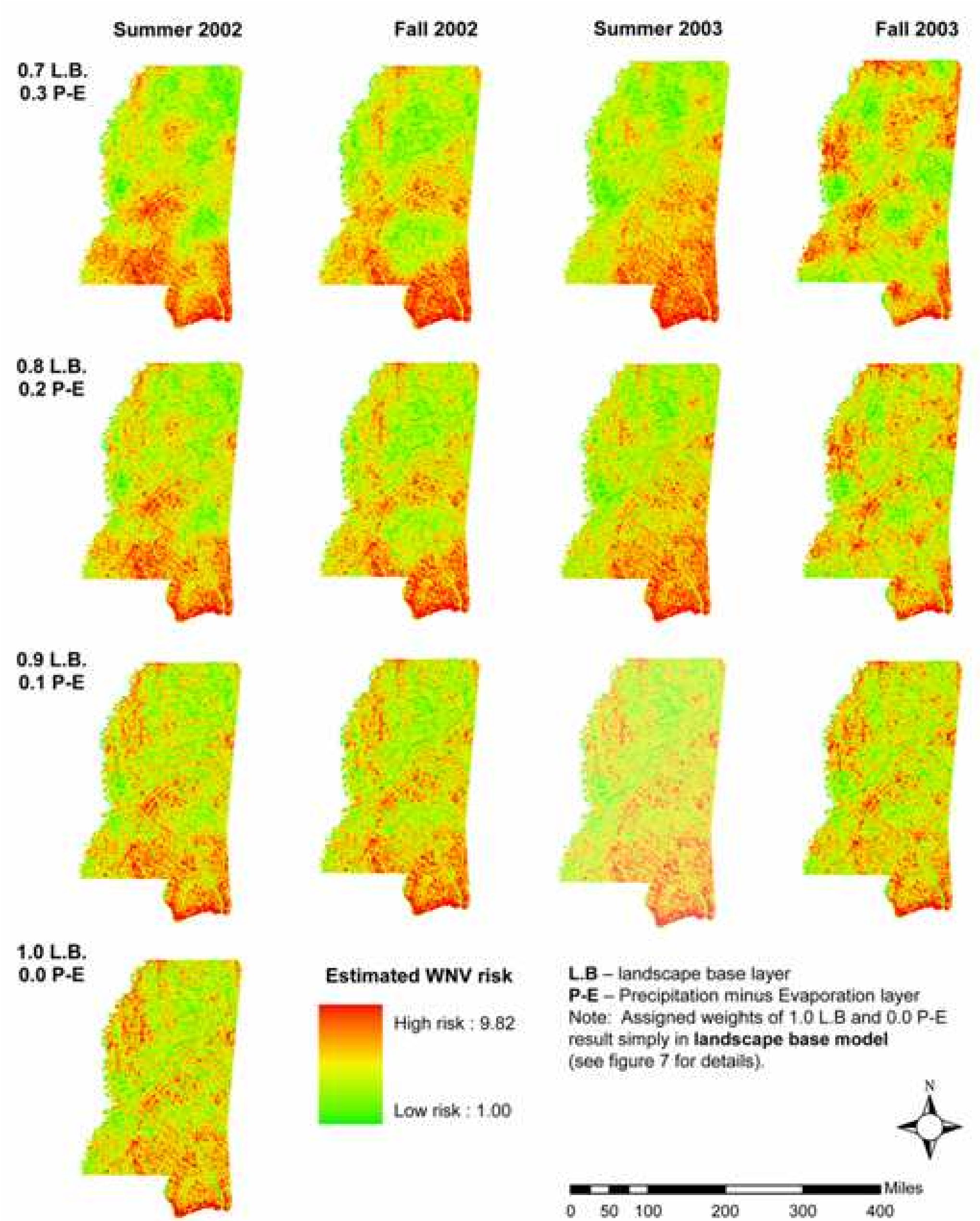
Landscape base model results by 120m cell



Estimated WNV risk median values summarized by zip code

Results of seasonal models

Results



0.7 * Landscape base + 0.3 * P-E

0.8 * Landscape base + 0.2 * P-E

0.9 * Landscape base + 0.1 * P-E

1.0 * Landscape base + 0.0 * P-E

Results of seasonal models

Results

• Addition of climate data improved risk estimation for summer models but worsened risk estimation for fall models.

• For summer models, when the ratio exceeded 0.8/0.2 the addition of climatic data diminished the predictability of the landscape base layer and did not improve the risk estimates.

• The ratio reached an optimum at 0.8 for landscape base layer and 0.2 for P-E layer.

• In general, 2003 models estimated WNV risk better than 2002 models.

• This might be associated with the fact that 2002 outbreak was considerably more severe, widely spread and therefore the risk more difficult to assess.

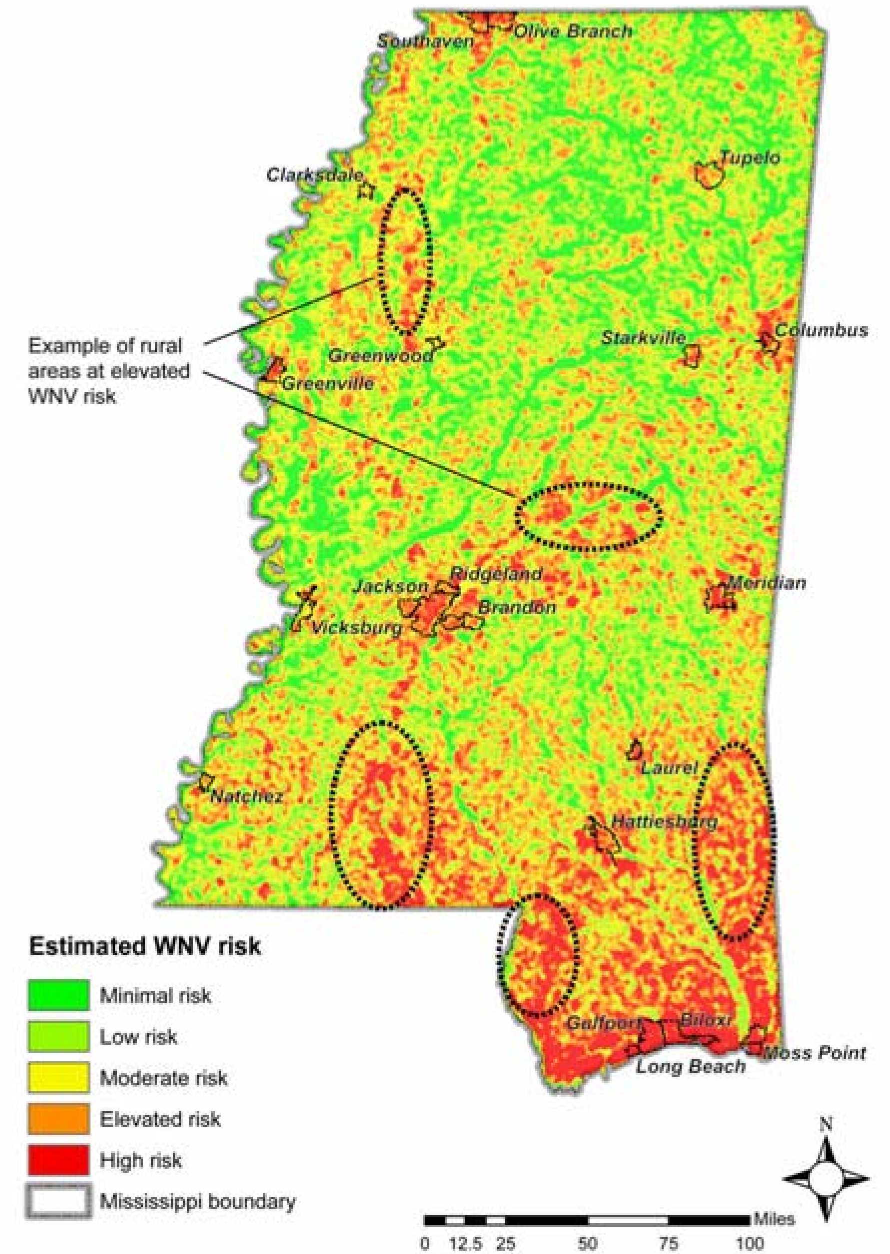
Estimated WNV risk

Areas at elevated WNV risk in Mississippi include:

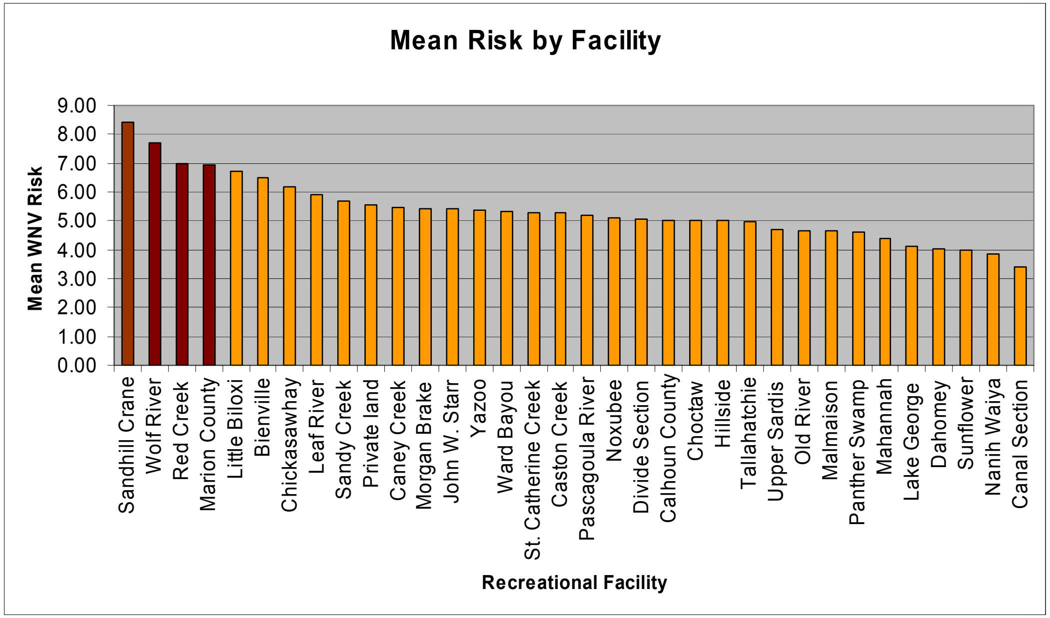
- **urban** areas (Gulf Coast, Jackson metropolitan center, Hattiesburg, Meridian and Columbus)
- numerous **rural** communities across the state

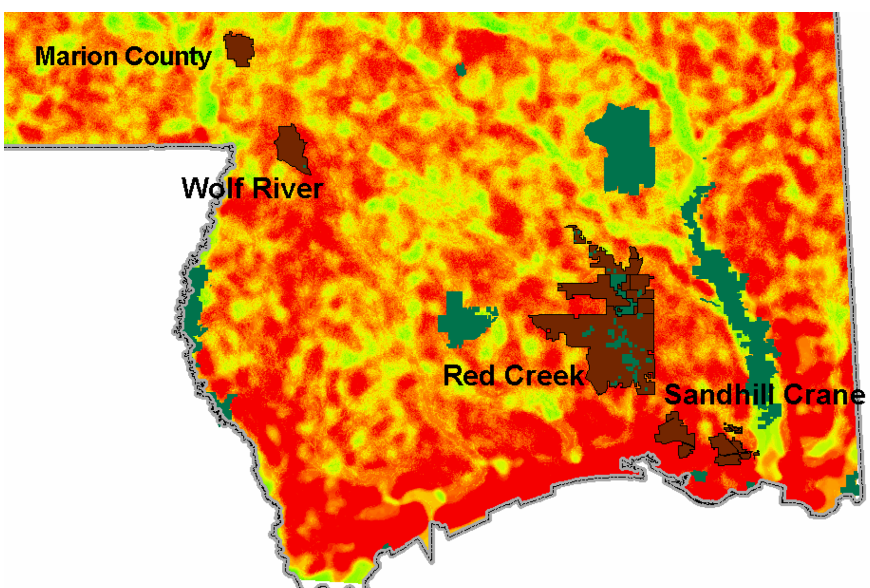
This contradicts the suggestion that WNV is predominantly an urban problem and indicates that WNV may be also a serious issue for rural areas.

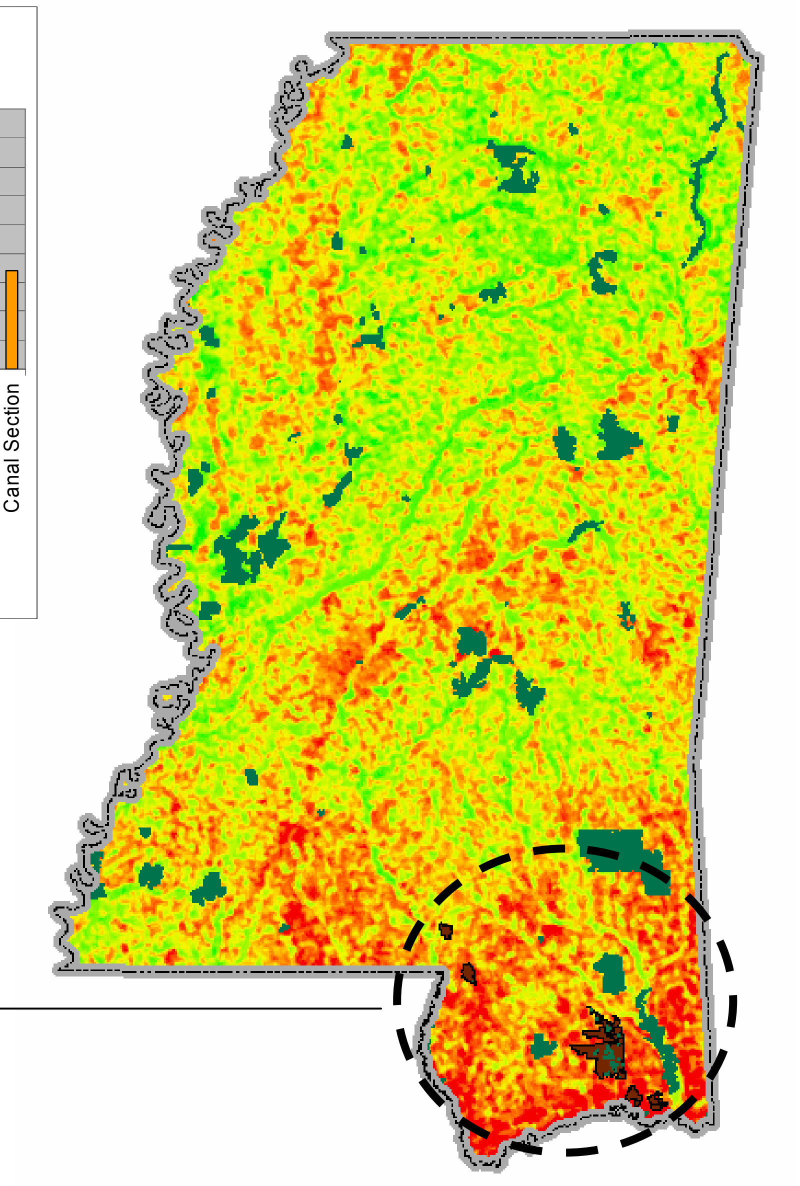
Summarization of risk across all seasons indicating areas environmentally prone to sustaining the WNV.



Estimated WNV risk by recreation area







Conclusions

• Statistical testing of variable significance provided deterministic evidence of each variables' importance (weight) for predicting risk using GIS.

• Bird-based WNV risk maps were validated with human case data and clearly show areas environmentally prone to sustaining the virus.

• Additive modeling gives a landscape-based detailed risk assessment at every cell location, which can be further summarized to show relative risk within other areas such as state parks, zip codes or recreation areas.

• Modeling provided information useful to better define mosquito control strategies and help regulatory agencies to focus their prevention efforts.

• The usefulness of climatic data in the models was not clearly demonstrated in this study.

Conclusions

- Research indicated that the assessment of WNV risk on a state level can be effectively performed using widely available environmental data combined with nonhuman surveillance information to support disease monitoring and prediction efforts.

- Our models were constructed in a desktop computing environment and can be easily implemented in an automated decision support system that may help public officials to be better prepared to combat this and other vector-borne diseases.

- Finally, modeling disease risk with GIS can optimize mosquito and bird sampling strategies designed for detection of WNV in the environment.

- This study shows that modeling avian infections with GIS indicates environmental conditions that place humans at risk for WNV infections.

Thank you