Shiny Application to Iowa DNR MSIM-SGCN Modeling

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Introduction

- Period: Oct 2015 - May 2016
- State Wildlife Grants - Iowa Department of Natural Resources
- Run predictive models using R package RMark
- Produce predictive maps using ArcGIS
- Develop an interactive web application using Shiny

Outline

- Project overview: data source and objectives
- Methods: model fit and covariates
- Model Validation: AUC
- Results: example of estimates table and predictive maps
- Demonstrate Shiny application

Data Collection

- Multiple Species Inventory and Monitoring (MSIM) Program
  - Iowa DNR and Iowa State University
- Sampling Interval
  - Primary: 2006-2014
  - Secondary: survey occasions (days)
- Survey Objects
  - 414 SGCN, only 69 SGCN where sufficient data were available
  - Birds, mammals, reptiles, amphibians, odonates and butterflies

Objectives

- Predict the distribution of species of conservation need
  - robust design occupancy model
- Create predictive species maps for priority SGCN
  - ArcGIS raster files
  - Shiny interactive web application
- Prioritize areas of conservation action for SGCN
  - habitat restoration and management

Methods

- Robust design occupancy model (MacKenzie et al. 2003)
  - package RMark
- Parameters of Interest
  - probability of occupancy (ψ)
  - probability of colonization (γ)
  - probability of extinction (ϵ)
  - probability of detection (p)
- Model types
  - RDOccupEG, RDOccupPE, RDOccupPG, ...

Statistical Model

$$Pr(\mathbf{X}_i) = \phi_0 \left\{ \prod_{t=1}^{T=1} D(\mathbf{p}_{X,t})\phi_t \right\} \mathbf{p}_{X,T}$$

- $\mathbf{p}_{X,t}$: vector denoting probability of observing the detection history $X_{i,t}$ in primary period t
- ϕ_t : matrix of transition probabilities between states of occupancy from primary period t to $t+1$

$$\phi_t = \begin{bmatrix} P(X_{t+1}=1|X_t=1) & P(X_{t+1}=0|X_t=1) \\ P(X_{t+1}=1|X_t=0) & P(X_{t+1}=0|X_t=0) \end{bmatrix}$$
$$= \begin{bmatrix} 1-\epsilon_t & \epsilon_t \\ \gamma_t & 1-\gamma_t \end{bmatrix}, t = 1, ..., \text{T-1}$$

$$\phi_0 = \begin{bmatrix} \psi_1 & 1-\psi_1 \end{bmatrix}$$

Example

$$Pr(\boldsymbol{X}_{i,1} = 010) = \psi_1(1 - p_{1,1})p_{1,2}(1 - p_{1,3})$$

$$Pr(\boldsymbol{X}_{i,2} = 000|\boldsymbol{X}_{i,1}) = (1 - \epsilon_1)\prod_{j=1}^{3}(1 - p_{2,j}) + \epsilon_1$$

$$\begin{aligned} Pr(\boldsymbol{X}_i = 010\ 000) &= \phi_0 D(\boldsymbol{p}_{010,1})\phi_1 \boldsymbol{p}_{000,2} \\ &= \begin{bmatrix} \psi_1 & 1 - \psi_1 \end{bmatrix} \begin{bmatrix} (1 - p_{1,1})p_{1,2}(1 - p_{1,3}) & 0 \\ 0 & 0 \end{bmatrix} \\ &\quad \times \begin{bmatrix} 1 - \epsilon_1 & \epsilon_1 \\ \gamma_1 & 1 - \gamma_1 \end{bmatrix} \begin{bmatrix} \prod_{j=1}^{3}(1 - p_{2,j}) \\ 1 \end{bmatrix} \\ &= \psi_1(1 - p_{1,1})p_{1,2}(1 - p_{1,3})\left[(1 - \epsilon_1)\prod_{j=1}^{3}(1 - p_{2,j}) + \epsilon_1\right] \end{aligned}$$

Statistical Model (cont'd)

- Including Covariates

$$\theta = \frac{exp(\boldsymbol{Z}'\beta)}{1 + exp(\boldsymbol{Z}'\beta)}$$

  - θ is the probability of interest
  - $\boldsymbol{Z}$ is the matrix of covariate information
  - β is the vector of logistic model coefficients to be estimated

Covariates

- Landscape habitat variables [1]
  - Radius of sampled site: 200m, 500m and 1km
  - Land use classification:
    Water, Wetland, Grassland, Woodland and Agriculture
  - Landscape configuration:
    percentage of landscape (PLAND), large patch index (LPI), edge density (ED), patch density (PD) and interspersion-juxtaposition (IJI)
- Climate variables [2]
  - Wind speed (km/h), Cloud cover (%), Temperature (°C)

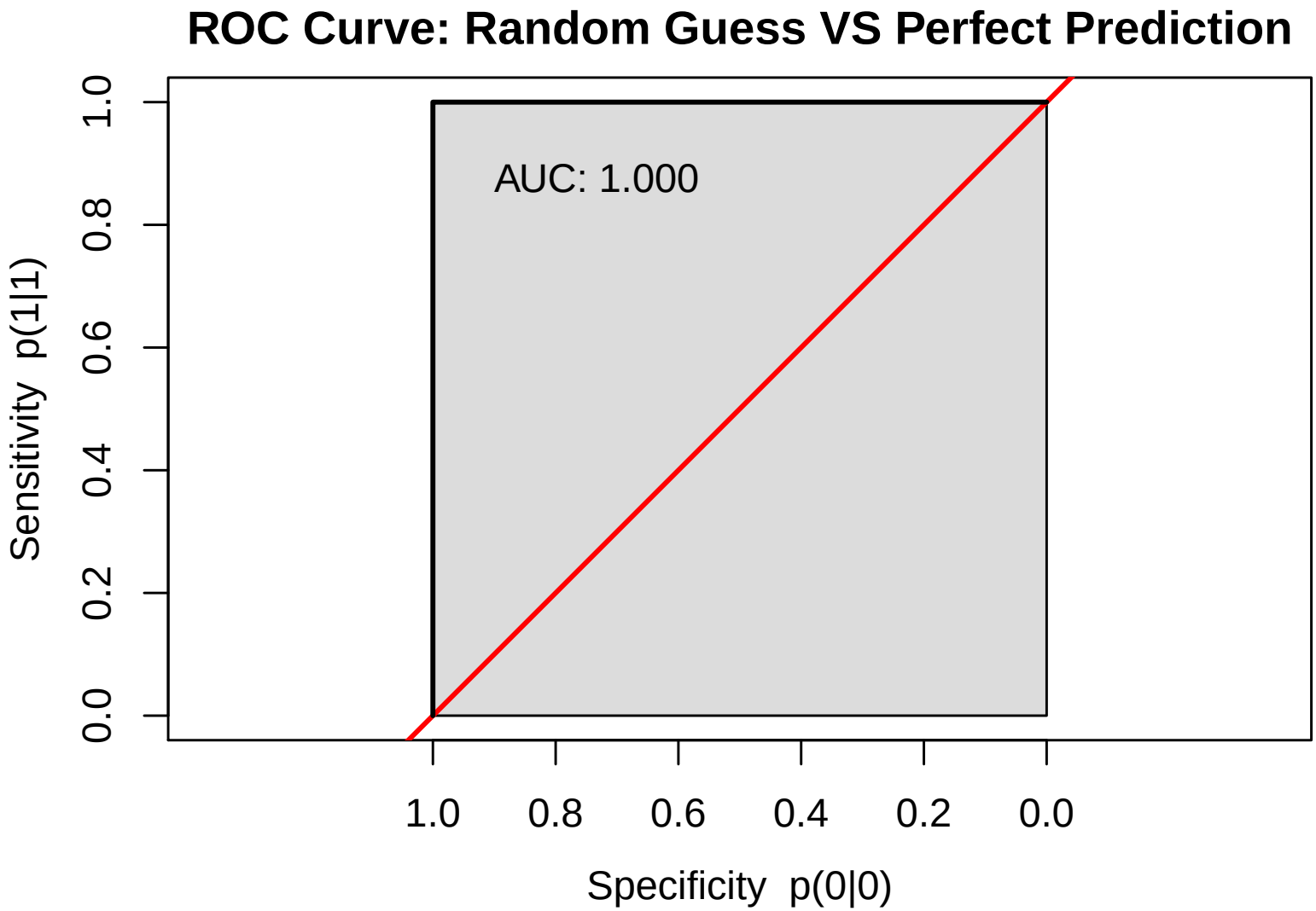
[1] site-specific, modeled on ψ, γ and ϵ

[2] time-varying, modeled on p

Model Selection and Validation

- Akaike's Information Criterion adjusted for small sizes (AIC_c)
  - Models with $\Delta AIC_c \leq 2 \Rightarrow$ strong support (Burnham and Anderson 2002)
- Area under the receiver operating characteristic curve (AUC)
  - evaluate performance of predicting occupancy
  - training data set: survey years 2006-2012, 2014
  - test data set: survey year 2013 (better representative)
  - package pROC
  - $AUC = 0.5 \Rightarrow$ random guess
  - $AUC = 1.0 \Rightarrow$ perfect prediction (Jimenez-Valverde 2012)

ROC Curve


ROC Curve: Random Guess VS Perfect Prediction
AUC: 1.000
Sensitivity p(1|1)
0.0
0.2
0.4
0.6
0.8
1.0
1.0
0.8
0.6
0.4
0.2
0.0
Specificity p(0|0)

Results

Table 1: Results Summary

Statistics	Value/Range
Number of SGCN modeled	64 out of 69
Occupancy Prob $\hat{\psi}$	0.001(0.0003)~0.995(0.004)
Colonization Prob $\hat{\gamma}$	0.0003(0.0001)~0.999(0.00007)
Detection Prob $\hat{p}$	0.030(0.028)~0.998(0.006)
AUC values	0.426~0.921
Number of AUC > 0.5	61 out of 64

Table 2: Best Models for Each Specie

Species	Model
Red-shouldered Hawk	ψ(Wod1KPLND)γ(Ag1KPD)p(Cld)
Yellow-billed Cuckoo	ψ(Wod500PLND)γ(Wod1kLPI)p(Wind)
Red-headed Woodpecker	ψ(Wod500PLND)γ(Ag500PD)p(Cld)
Eastern Wood-pewee	ψ(Wod500PLND)γ(Wod1KPLND)p(Wind)
Acadian Flycatcher	ψ(Wod500PLND)γ(Wod500PLND)p(Wind)
Veery	ψ(Wod1kED)γ(Ag500LPI)p(Wind)

Table 3: AUC and Coefficients Estimates under Best Model

Species	AUC	Psi.Cov	Gam.Cov	p.Cov
Red-shouldered Hawk	0.798	0.034	0.002	-0.008
Yellow-billed Cuckoo	0.706	0.060	0.042	-0.076
Red-headed Woodpecker	0.610	0.017	-0.002	-0.004
Eastern Wood-pewee	0.906	0.128	0.071	-0.110
Acadian Flycatcher	0.892	0.092	0.070	0.086
Veery	0.551	0.005	-0.578	0.179

Yellow-billed Cuckoo Colonization

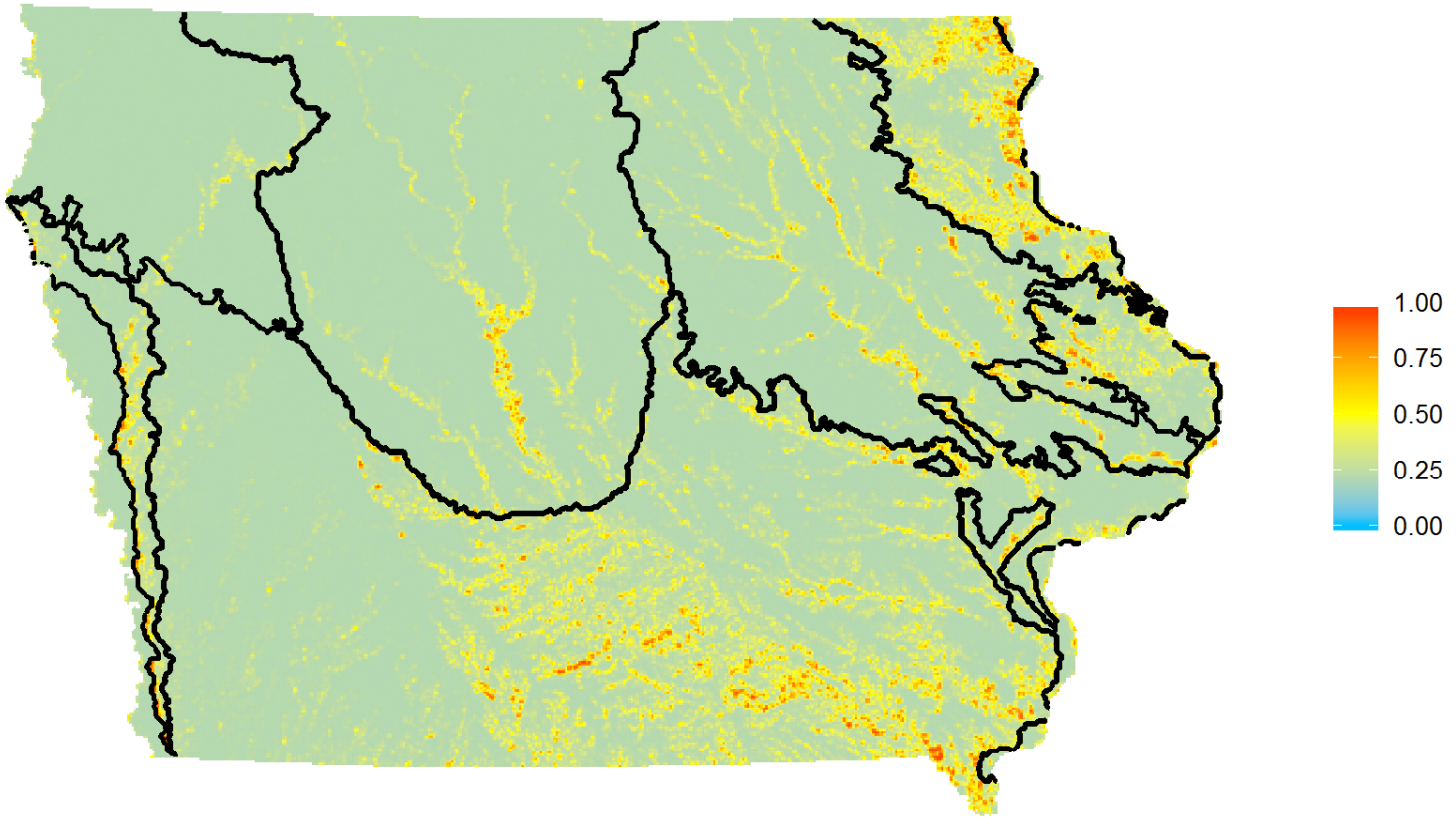


Figure 1: Predictive Map

Red-shouldered Hawk Occupancy

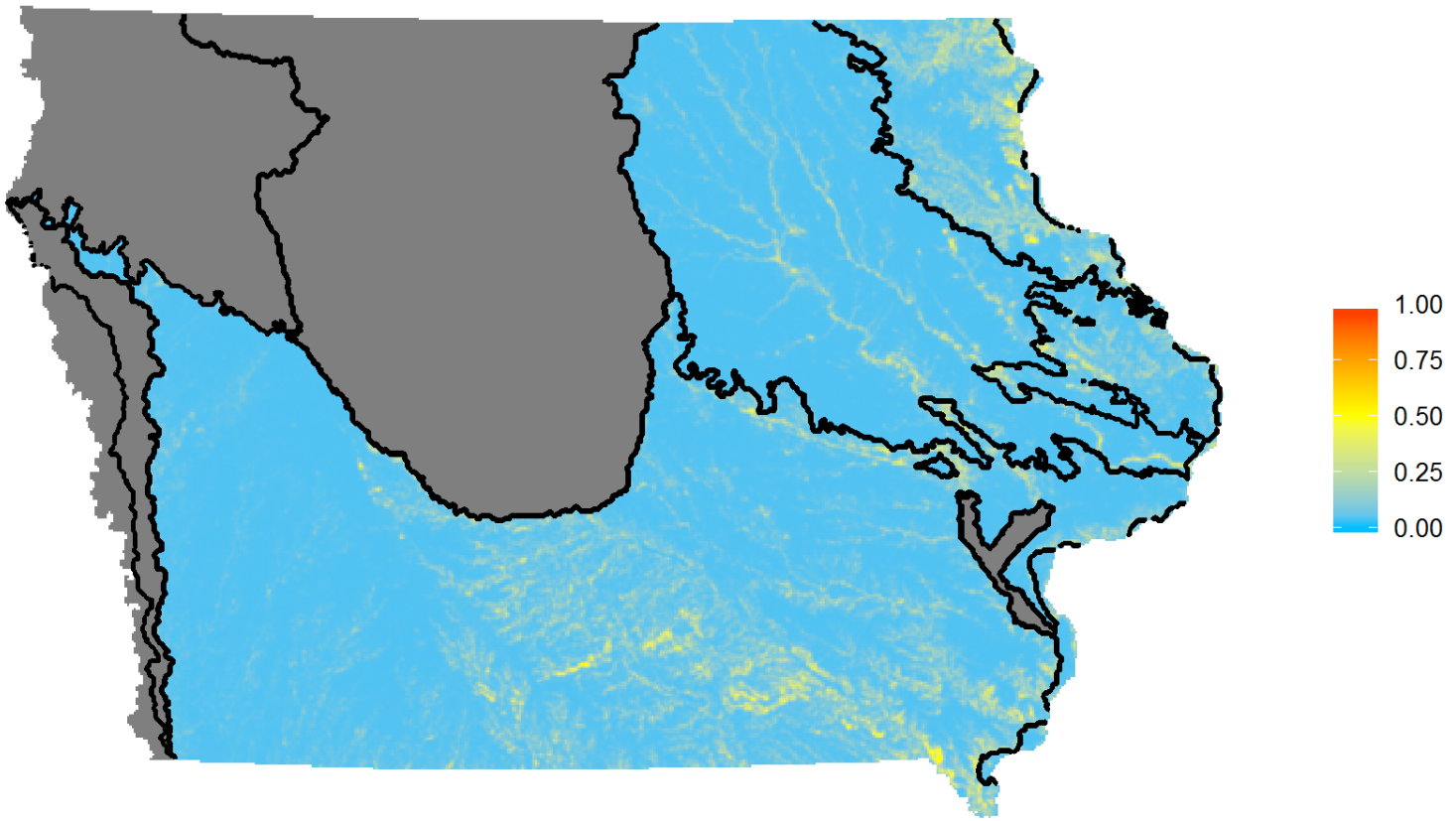


Figure 2: Predictive Map of Range-Restricted Specie

Shiny

- **Shiny** by RStudio is a web application framework for R.
- No HTML, CSS or JavaScript knowledge required to turn your analyses into interactive web applications.

```
install.packages("shiny")
library("shiny")
runExample("01_hello")
```

- ui.R defines the page layout and user interface
- server.R contains the R code to create any output
- More information available at Shiny Webpage

About Our Shiny Application

- Interactive web application to display predictive maps and parameter estimates for each SGCN
- Easy to download personalized data and maps
- Available to researchers and managers across Iowa (credentials needed)
- Hosted by CSSM for 1-2 years
- The URL for accessing the application is https://dnrswg.cssm.iastate.edu/