Survey and Analysis Design for Wood Turtle Abundance Monitoring Programs

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Species Status

- IUCN: Endangered
- COSEWIC: Threatened
- US ESA: Under Review

- Found in 17 US States
  - Not listed as a Species of Concern in Maryland and Pennsylvania

- Upper Midwest
  - Minnesota: Threatened
  - Wisconsin: Species of Concern
  - Michigan: Species of Concern
  - Iowa: Endangered
Competitive State Wildlife Grant (CSWG)

• 2014‒2016; 2017‒2018

Management
• Nesting site creation/restoration
• Nest protection
• Road barriers

Monitoring/Research
• Population surveys
• Telemetry and GPS tracking
• Nest monitoring
• Road mortality monitoring
MN Wood Turtle Research Goals/Status

Individual-level research
• Assess diel and seasonal movement and habitat use patterns
  ▪ M. Cochrane thesis (summer 2017)
• Track individual responses to habitat management actions
  ▪ Ongoing

Population-level research
• Influence of nest site protection on hatchling production
  ▪ Ongoing
• Determine if detectable changes in population size and structure have occurred over the last 25 years
  ▪ Manuscript in review (Herpetological Conservation and Biology)
• Develop a survey and analysis protocol to monitor abundance over time
Relevance to LSFSC

- Species of concern that occurs in much of the focal region
- Riverine species, but largely terrestrial during their active period
  - Directly affected by terrestrial habitat changes

Relevance to LSFSC

• Species largely found in primarily forested regions

• Can travel up to ~0.5 km from the river

• Within upland areas, early-successional habitat is heavily used
  ▪ Necessary habitat feature for nesting sites
  ▪ Adults show preference for young forest and forest openings (Compton et al. 2002, Brown et al. 2016)

• Fire could potentially improve habitat quality, but remains unstudied
  ▪ Thermoregulation, foraging habitat


Need for a Standardized Monitoring Design

• State agencies in the Upper Midwest are interested in creating long-term abundance monitoring programs
  ▪ Track population trends and responses to active management

• Benefits of a standardized monitoring design:
  ▪ Direct comparability of results among states and monitoring sites
    ➢ Can track abundance trends across multiple scales
  ▪ Increased spatial replication (can improve model performance)
  ▪ If coordinated among states, can decrease total time spent on data management and analyses
  ▪ Results in large spatial and temporal data sets that are useful for research
Survey Design Considerations

- Literature review, discussions with regional wood turtle biologists, pilot study (2015)

Sampling method
- Passive sampling with aquatic traps (Ratner and Anderson 1978, Akre 2002)
- Active sampling by boat of shorelines, transparent streams (Buech et al. 1997, Daigle 1997, Saumure and Bider 1998)
- Active sampling by foot of upland habitat, riparian habitat, transparent streams (Brooks et al. 1992, Greaves and Litzgus 2009)
  - Comparatively high detection rates
  - No trap requirement
Survey Design Considerations

Length of river to survey
• ~0.5 km based on a pilot study (2015) and previous research on movement patterns in the study area (Brown et al. 2016)

Distance from river to survey
• Tested in study
• 4 survey bands on each side of the river, transects spaced at 15 m intervals

When to survey
• Spring to maximize detections (Jones et al. 2015)
• Within spring: tested in study

How many times to survey
• Tested in study
• Up to 8 replications
Survey Implementation

- **Surveys conducted during spring 2016**
  - 30 April – 5 June

- **8 potential long-term monitoring sites**
  - Mix of management and control sites
  - 380 – 558 m stretches of river

- **4 surveyors**
  - 2 on each side of river
  - 0.8 – 4.7 hrs / survey ($\bar{x} = 1.7$)
Analysis Design Considerations

Model Class

• Generalized linear models (GLM) / random effects models
  ▪ Do not explicitly account for detection probability

• Capture-recapture models
  ▪ Powerful models, but reliant on high capture and recapture success for model convergence and/or precise estimates
  ▪ Previous research: Generally required ≥9 survey replications to estimate wood turtle population abundance (Jones et al. 2015)

✓ N-mixture models (Royle 2004)
  ▪ More flexible, do not require sites to contain many individuals
  ▪ Marking individuals is not a requirement, but information can be used if available
  ▪ Can accommodate common issues in monitoring program data sets: variation in survey area, variation in effort among sites and years (including no site surveys in some years)
**N-mixture Model Overview**

Two linked GLMs to correct biases in raw count data

- **State process:** Estimated abundance ($N$) at site $i$, based on a Poisson distribution with $\lambda = \text{mean abundance over all sites}$
  - Can also use zero-inflated Poisson and negative binomial distributions

- **Observation process:** $N_i$ informed by raw count data ($C$) and per-individual detection probability ($p$)

- Model allows covariates to influence $N$ and $p$ independently

**Survey data options:**

- Simple counts, **removal sampling**, double observer sampling, distance sampling, false absences & presences

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**No covariates**

1. State process: $N_i \sim \text{Poisson}(\lambda)$
2. Observation process: $C_{ij|N_i} \sim \text{Binomial}(N_i, p)$

**Covariates**

- $N_i \sim \text{Poisson}(\lambda_i)$, with $\log(\lambda_i) = \beta_0 + \beta_1 \times \text{vegHt}_i$
- $C_{ij|N_i} \sim \text{Binomial}(N_i, p_{ij})$, with $\logit(p_{ij}) = \alpha_0 + \alpha_1 \times \text{wind}_{ij}$
Methods: Survey Design Delineation

Goal: Balance survey effort and data quality
• Optimal number: Mean abundance within ~10% of the full model

Field data: Influence of transects and survey replications
• Compared reduced data sets to full data set
  ▪ Transects: 1, 1–2, 1–3, 1–4
  ▪ Survey replicates: 3–8
• Assumption: More data = higher accuracy ($N$ unknown)
Methods: Survey Design Delineation

Simulations: Influence of surveys replications and sites

• Compared reduced data sets to full data set
  ▪ Survey replications: 3–8 (100 sites)
  ▪ Sites: 5, 10, 15, 20, 40 (8 surveys)

• Assumption: Parameter values reflect reality ($N$ known)
  ▪ Parameterized based on field data results
  ▪ 1,000 replications per simulation

Metric: $\hat{N} / N$

• On average, should be close to 1 if the model is suitable
• Assessed changes in precision (25th–75th percentiles)
Results: Individual Detections

- 64 surveys (8 sites, 8 replications)

**Individual detections**
- 313 individual detections
  - Per site: 4–95 ($\bar{x} = 39$)
- 174 unique individuals
  - Per site: 3–54 ($\bar{x} = 22$)

**Transect detections**
- 1: 35.7%
- 2: 33.9%
- 3: 18.9%
- 4: 11.5%
Results: Optimal Design (Field Data)

**Transects**
- $\bar{x}$ abundance for transects 1–2 within 10% of 1–4
  - Precision similar for transects 1–3 and 1–4

**Surveys**
- $\bar{x}$ abundance for 6 surveys within 11% of 8
Results: Optimal Design (Simulations)

Surveys
• Precision similar when ≥6 surveys are completed

Sites
• Precision similar when ≥15 sites are surveyed
Important Survey Covariates

Benefits of assessing/modeling survey covariates:

- Define optimal sampling times (increase baseline $p$)
- Improve model fit
- Improve understanding of species behavior

Survey covariates tested

- Day of year (linear and quadratic)
  - 121–157 ($\bar{x} = 142$)
- Air temperature (linear and quadratic)
  - 10.3–31.8 °C ($\bar{x} = 20.9 °C$)
- Survey start time
  - 0845–1700 ($\bar{x} = 1203$)
- Leaf-out
  - Pre-leaf-out, early-leaf-out
- Visibility
  - Sunny-partly cloudy, overcast-rainy
Results: Survey Covariates

- Temperature (quadratic) model had the most support
  - Maximum $p$ 19–23 °C (66–73 °F)

<table>
<thead>
<tr>
<th>Structure</th>
<th>Parameters</th>
<th>QAIC$_c$</th>
<th>ΔQAIC$_c$</th>
<th>$w_i$</th>
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<td>$p$(TempQ)</td>
<td>12</td>
<td>107.44</td>
<td>0.00</td>
<td>0.53</td>
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<td>$p(.)$</td>
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<td>$p$(TempQ+LeafOut)</td>
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<td>$p$(DayL)</td>
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<td>118.00</td>
<td>10.56</td>
<td>0.00</td>
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<tr>
<td>$p$(TempL+LeafOut)</td>
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<td>120.78</td>
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<tr>
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<tr>
<td>$p$(Visibility)</td>
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<td>123.42</td>
<td>15.99</td>
<td>0.00</td>
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</tbody>
</table>
Results: Survey Covariates

- Temperature (quadratic) model had the most support
  - Maximum $p$ 19–23 °C (66–73 °F)
Other Considerations: Demography

• Surveying 1-2 vs 1-4 transects could affect demographic estimates if spatial habitat use patterns differ

• Compared results based on surveying 1–2 vs 1–4 transects
  ▪ Sex ratio (proportion of male adults/sub-adults)
  ▪ Size (mean straightline carapace length)

• Paired randomization tests with 10,000 iterations (Sokal and Rohlf 1995)
  ▪ Paired sites randomized by transect sampling design
Results: Demography

- No difference in $\bar{x}$ size
  - $P = 0.542$
- No difference in $\bar{x}$ sex ratio
  - $P = 0.681$
Other Considerations: Single-side Surveys

Potential survey modification

- Land ownership restrictions
- Logistical or physical difficulties accessing both sides

Estimated abundance on each side of the river

- Individuals were unique when captured on each side
Results: Single-side Surveys

- Abundance usually underestimated
  - Indicates non-random heterogeneity in $p$ (preference for one side)

<table>
<thead>
<tr>
<th>Site Code</th>
<th>Site</th>
<th>Sub-site (low)</th>
<th>$n$ (low)</th>
<th>Sub-site (high)</th>
<th>$n$ (high)</th>
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</thead>
<tbody>
<tr>
<td>BO</td>
<td>4.6</td>
<td>2.0</td>
<td>1</td>
<td>5.9</td>
<td>3</td>
</tr>
<tr>
<td>CUT</td>
<td>7.7</td>
<td>5.9</td>
<td>3</td>
<td>7.9</td>
<td>4</td>
</tr>
<tr>
<td>GLN</td>
<td>6.6</td>
<td>0.0</td>
<td>0</td>
<td>8.4</td>
<td>5</td>
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<tr>
<td>IL</td>
<td>76.7</td>
<td>40.6</td>
<td>22</td>
<td>73.8</td>
<td>40</td>
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<tr>
<td>LG</td>
<td>36.4</td>
<td>26.4</td>
<td>14</td>
<td>30.2</td>
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</tr>
<tr>
<td>NLG</td>
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<td>3.6</td>
<td>2</td>
<td>9.1</td>
<td>5</td>
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<tr>
<td>SP</td>
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<td>27.7</td>
<td>16</td>
<td>43.4</td>
<td>25</td>
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<tr>
<td>TR</td>
<td>62.2</td>
<td>40.8</td>
<td>23</td>
<td>62.1</td>
<td>35</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>247.5</strong></td>
<td><strong>147.0</strong></td>
<td></td>
<td><strong>240.8</strong></td>
<td></td>
</tr>
</tbody>
</table>
Other Considerations: Occupancy Surveys

**Sometimes presence/absence is sufficient**

- Land-use permitting; species occurrence lists/locations
- Distribution monitoring: number, location, and connectivity of populations

**Two approaches:**

- **Model-based:** Estimate presence/absence using occupancy modeling
  - Predictive model covariates for state and observation processes

- **Design-based:** Conduct sufficient number of surveys to be confident in presence/absence
  - Predictive model covariates for state process only

**Simulations**

- Binomial probability distribution simulations
- Values based on field survey data using 2 transects
  - Low: 0.25; Mod: 0.5; High: 0.75

1. State process: $z_i \sim \text{Bernoulli}(\psi)$
2. Observation process: $y_{ij|z_i} \sim \text{Bernoulli}(z_i p)$
Methods/Results: Occupancy Surveys

Maximum # surveys required for presence confirmation

- ≥95% of trials
  - Low: 11; Mod: 5; High: 3
- 100% of trials
  - Low: >12; Mod: 10; High: 6

Field data

- Worst detection site: 10000010
- Best detection site: 11111111
- Median: 6/8
Future Research Directions

2017

• Use protocol for additional site surveys (Minnesota)
• Further research on potential for single-side surveys
  ▪ Test $N$-mixture temporary emigration model (Wisconsin)
• Replicate abundance surveys at study sites
  ▪ Use open population model to estimate annual survivorship

Future

• Assess habitat associations (regional)

\[
N_i \sim \text{Poisson}(\lambda_i), \text{ with } \log(\lambda_i) = \beta_0 + \beta_1 \times \text{vegHt}_i
\]

\[
C_{ij} | N_i \sim \text{Binomial}(N_i, p_{ij}), \text{ with } \logit(p_{ij}) = \alpha_0 + \alpha_1 \times \text{wind}_{ij}
\]
Potential for Protocol Use/Integration in Eastern US and/or Canada

• Midwest US protocol shares a lot of similarities with eastern US protocol
  ▪ A few important differences

• Canada currently lacks standardized protocol

<table>
<thead>
<tr>
<th>Survey Attribute</th>
<th>Midwest US</th>
<th>Eastern US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling method</td>
<td>Active by foot</td>
<td>Active by foot (or boat)</td>
</tr>
<tr>
<td>Length of river surveyed</td>
<td>Shorter (~0.5 km)</td>
<td>Longer (~1 km)</td>
</tr>
<tr>
<td>Distance from river surveyed</td>
<td>~25/40 m (2/3 transects)</td>
<td>≤10 m</td>
</tr>
<tr>
<td>When to survey</td>
<td>Spring</td>
<td>Spring (preferred) or fall</td>
</tr>
<tr>
<td># Replications</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td># Surveyors</td>
<td>1+, no lead surveyer</td>
<td>1+, 1 lead surveyer</td>
</tr>
<tr>
<td>Time constraint</td>
<td>None *record survey time</td>
<td>1 hr, excluding processing time</td>
</tr>
</tbody>
</table>

Acknowledgments

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• US Forest Service: Dan Ryan, Mark Nelson; Fond du Lac Reservation: Mike Schrage

Survey assistance
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