Survey and Analysis Design for Wood Turtle Abundance Monitoring Programs

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Lake States Fire Science Consortium Webinar, 16 Mar 2017

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)

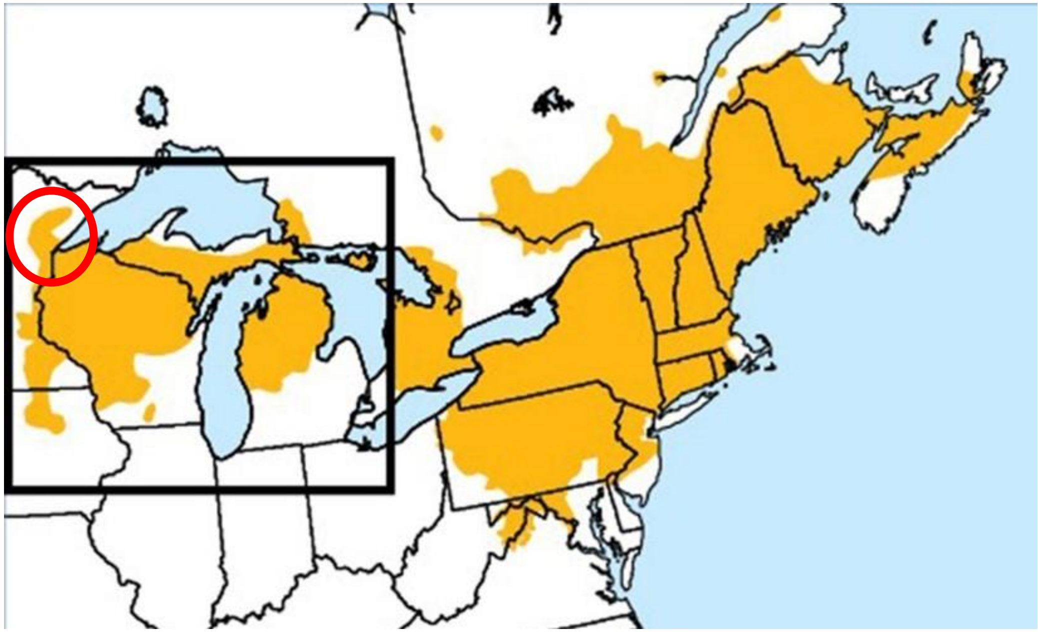
- 2014–2016; 2017–2018

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

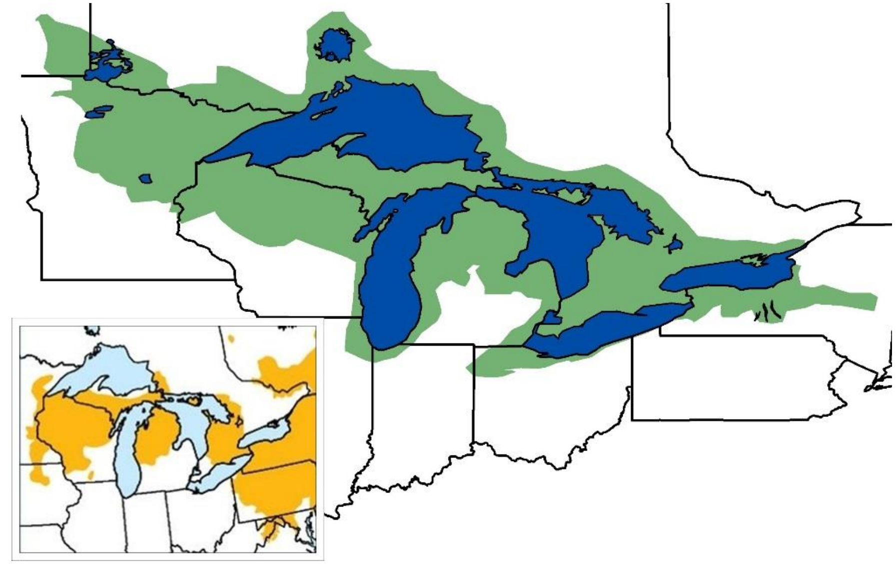
Individual-level research

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

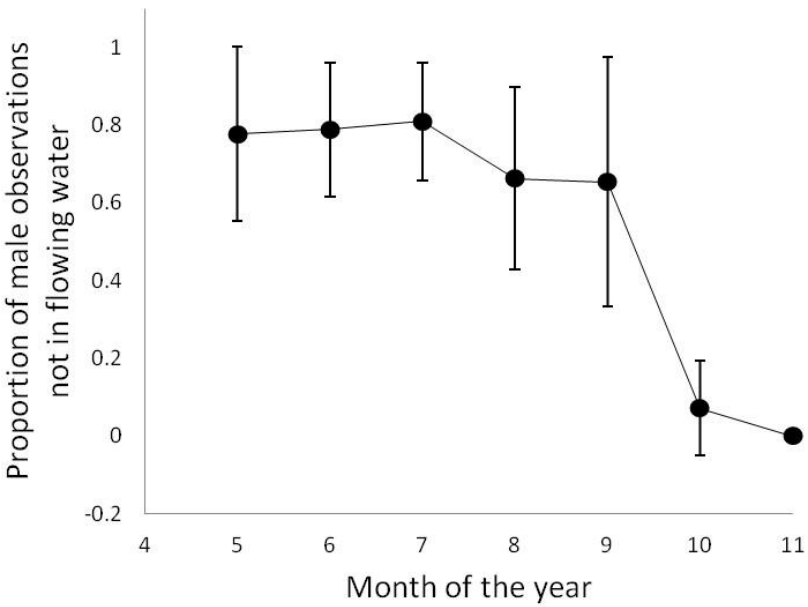
Population-level research

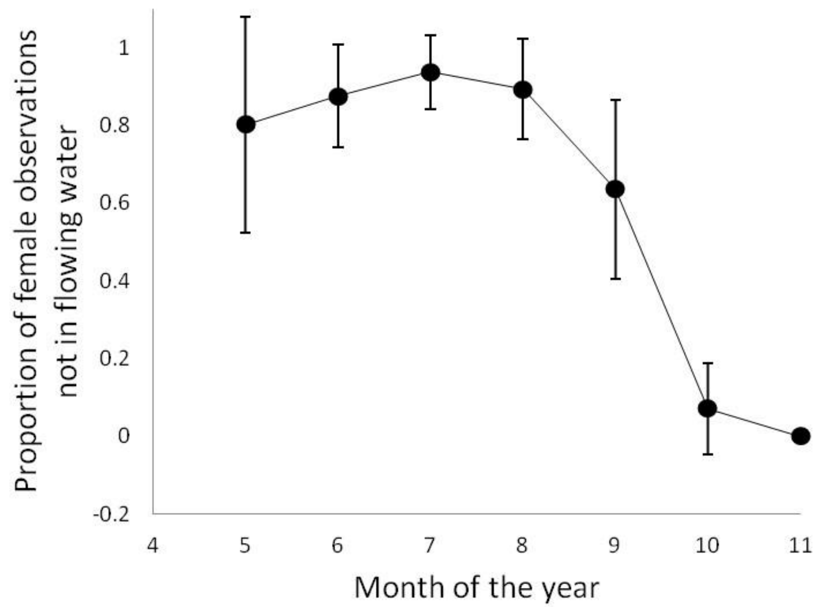
- Influence of nest site protection on hatchling production
  - Ongoing
- Determine if detectable changes in population size and structure have occurred over the last 25 years
  - Manuscript in review (Herpetological Conservation and Biology)
- **Develop a survey and analysis protocol to monitor abundance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

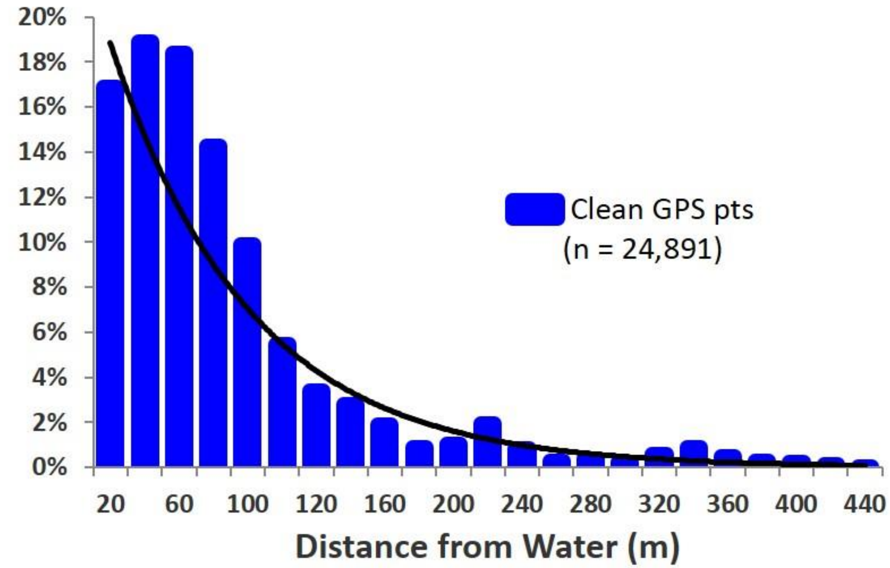




Brown, D. J., M. D. Nelson, D. J. Rugg, R. R. Buech, and D. M. Donner. 2016. Spatial and temporal habitat-use patterns of wood turtles at the western edge of their distribution. Journal of Herpetology 50:347–356.

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



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Compton, B. W., J. M. Rhymer, and M. McCollough. 2002. Habitat selection by wood turtle (*Glyptemys insculpta*): an application of paired logistic regression. Ecology 83:833–843.

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

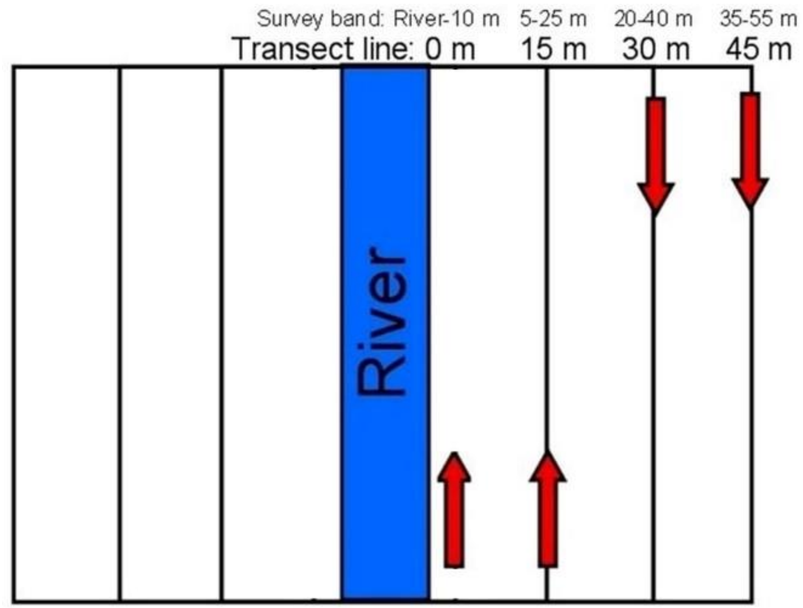
Survey Design Considerations

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

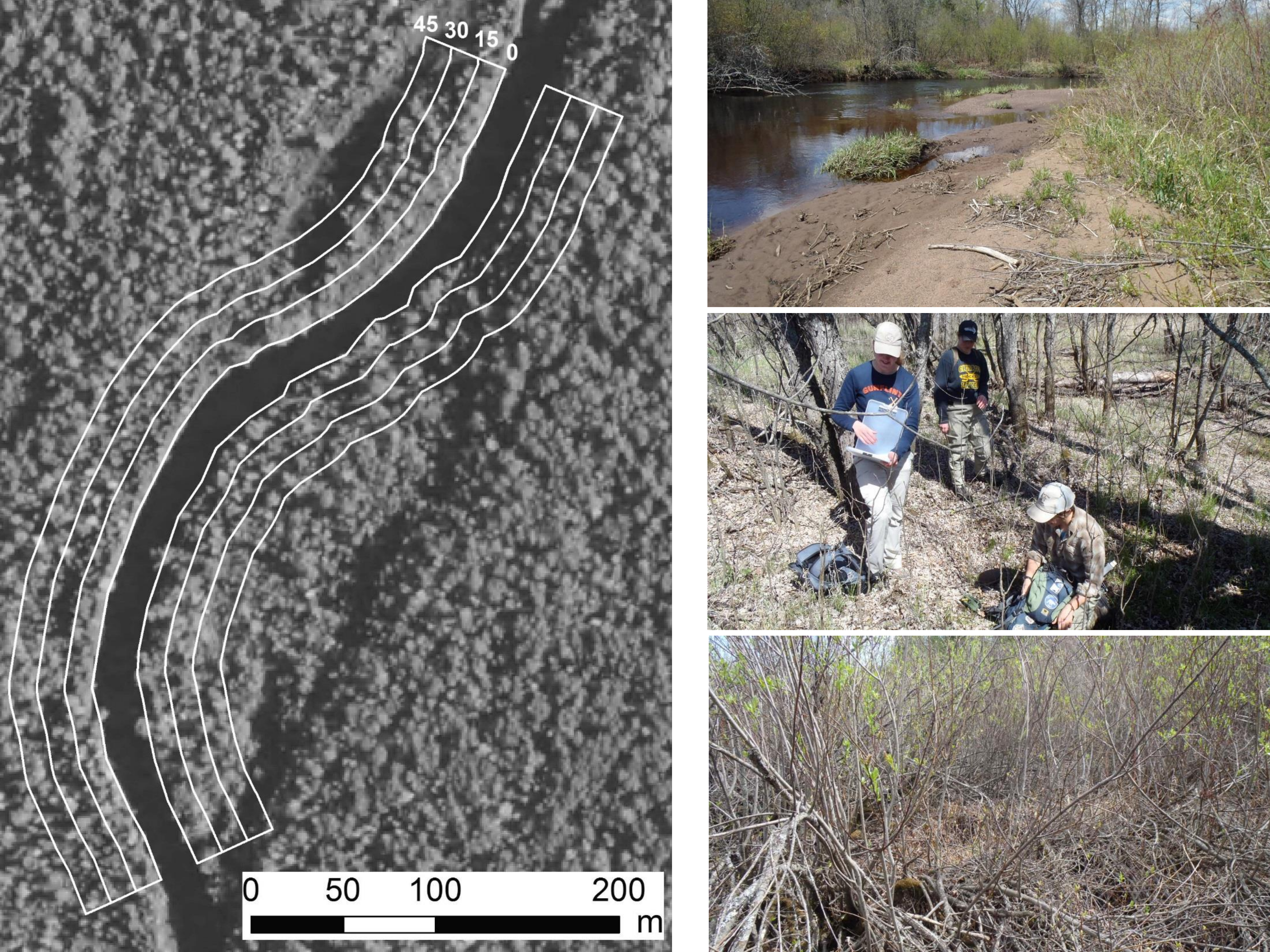
- Spring to maximize detections (Jones et al. 2015)
- Within spring: tested in study

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)


45
30
15
0
0
50
100
200
m

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 λ = 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

No covariates

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

Covariates

$$N_i \sim Poisson(\lambda_i), \text{ with } \log(\lambda_i) = \beta_0 + \beta_1 * \text{vegHt}_i$$

$$C_{ij}|N_i \sim Binomial(N_i, p_{ij}), \text{ with } \text{logit}(p_{ij}) = \alpha_0 + \alpha_1 * \text{wind}_{ij}$$

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 (25^{th}–75^{th} percentiles)

Results: Individual Detections

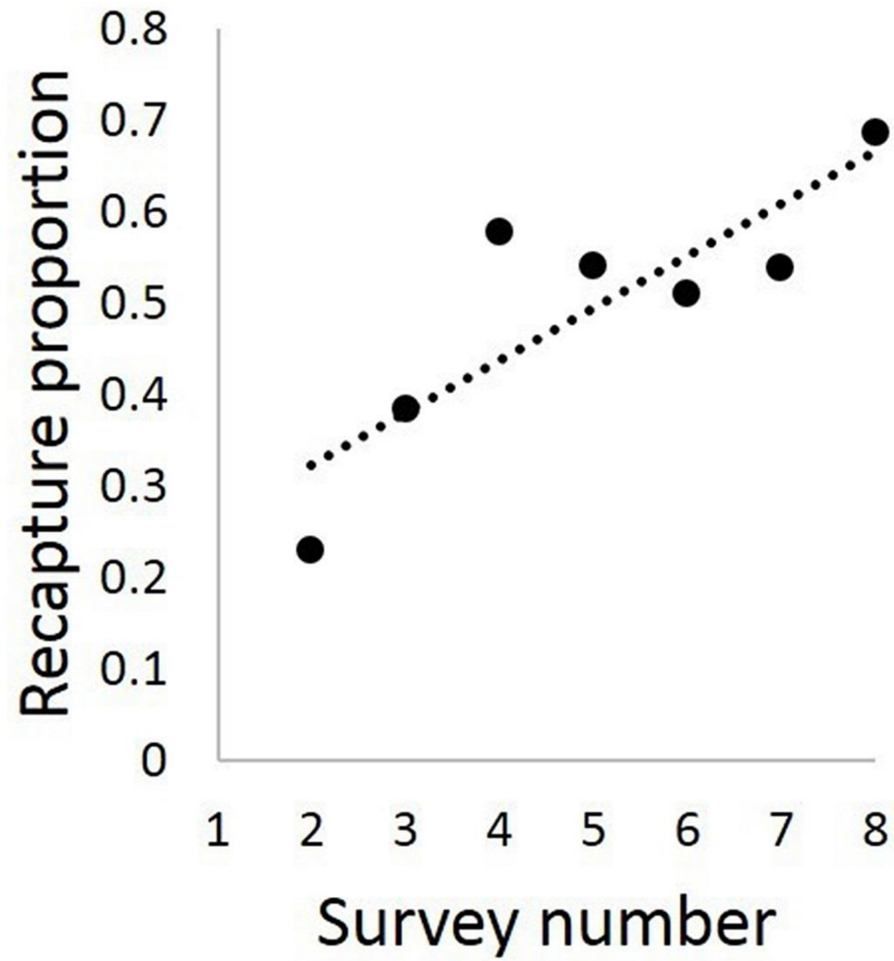
- 64 surveys (8 sites, 8 replications)

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%



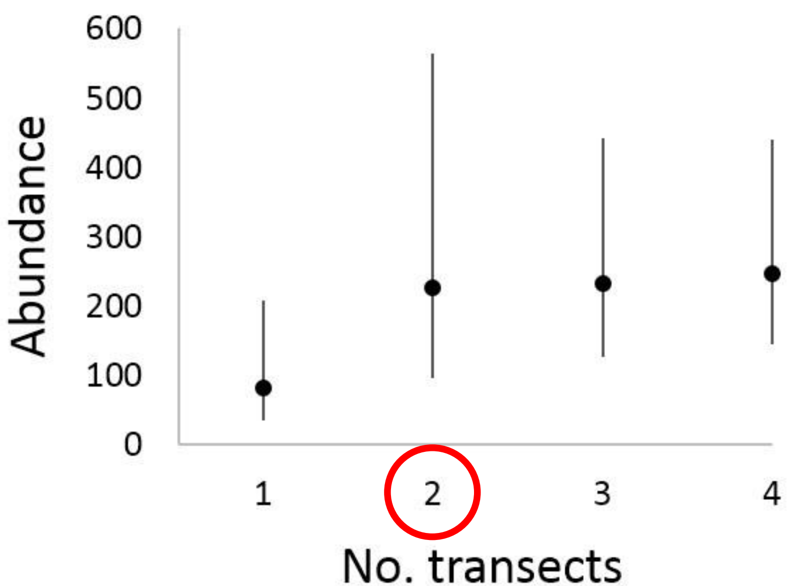
Results: Optimal Design (Field Data)

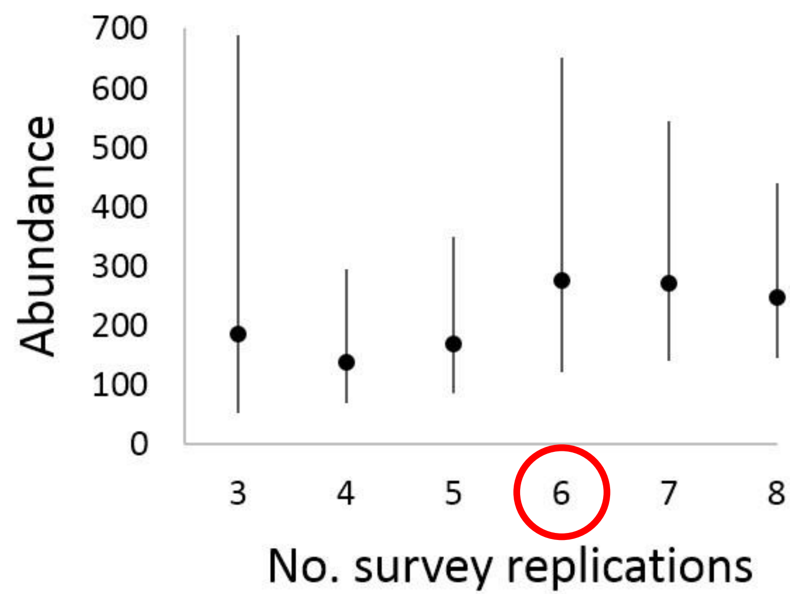
Transects

- $\bar{x}$ 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





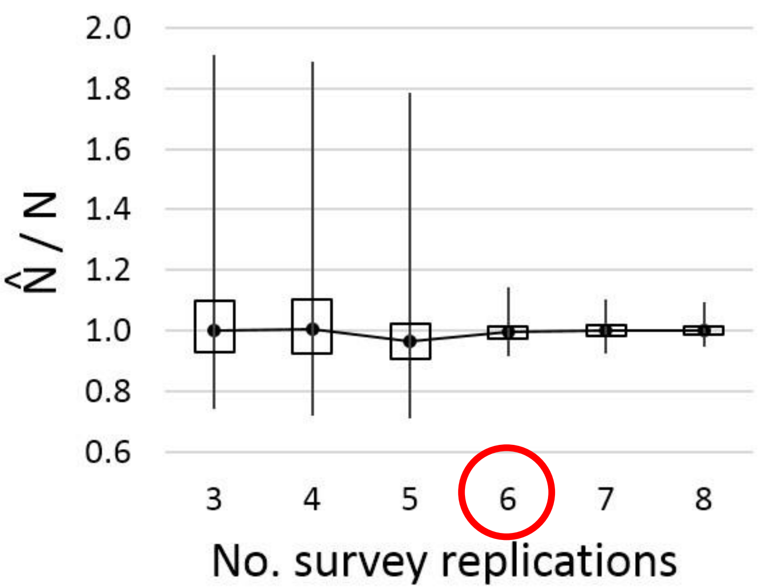
Results: Optimal Design (Simulations)

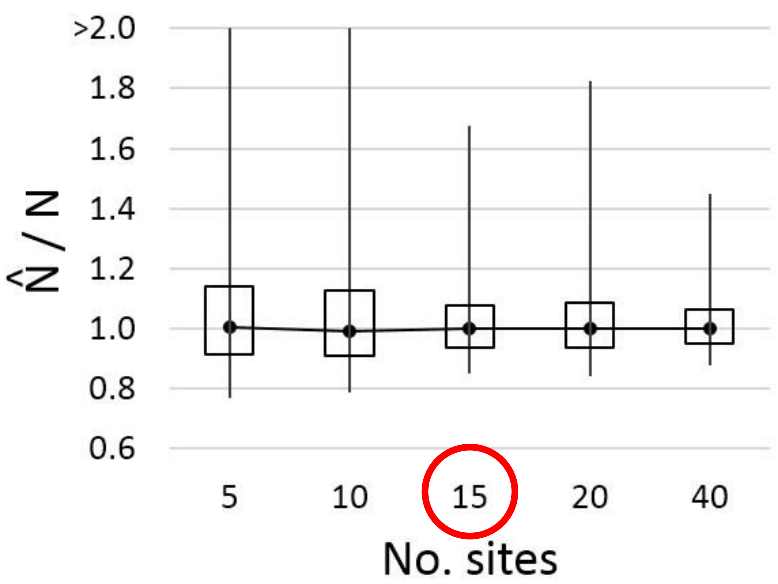
Surveys

- 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

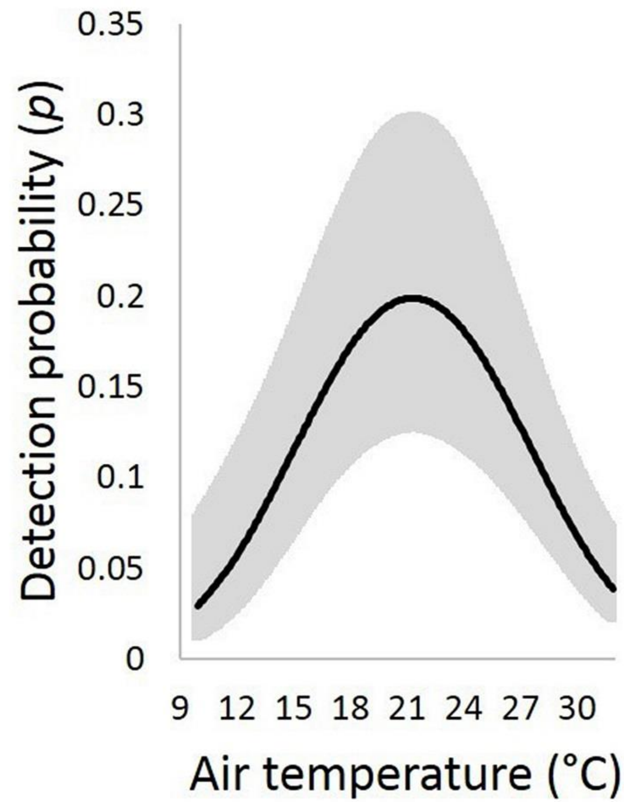
Survey covariates tested

- 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)

Structure	Parameters	$QAIC_c$	$\Delta QAIC_c$	w_i
p(TempQ)	12	107.44	0.00	0.53
p(.)	10	108.92	1.49	0.25
p(TempQ+LeafOut)	13	109.23	1.80	0.21
p(TempL)	11	117.19	9.75	0.00
p(DayL)	11	118.00	10.56	0.00
p(TempL+LeafOut)	12	120.78	13.35	0.00
p(DayQ)	12	121.02	13.58	0.00
p(Visibility)	11	123.42	15.99	0.00



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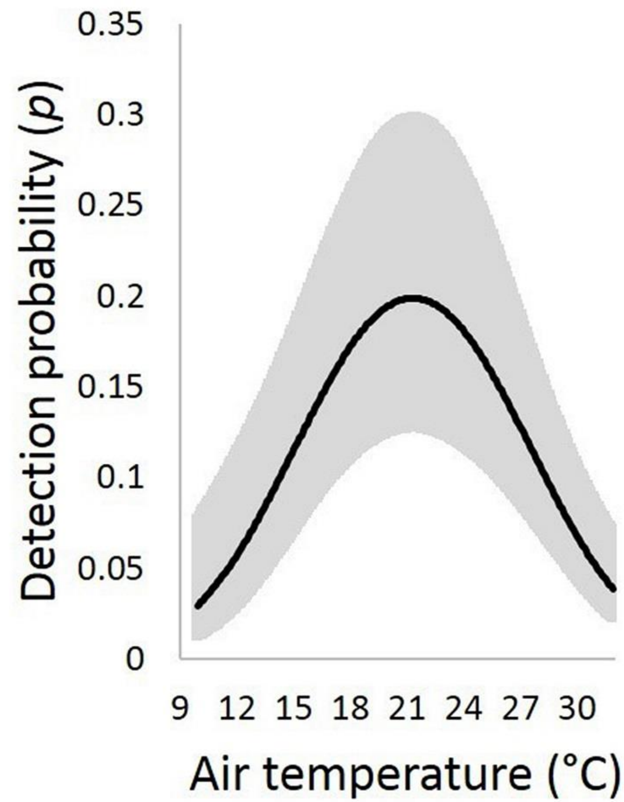
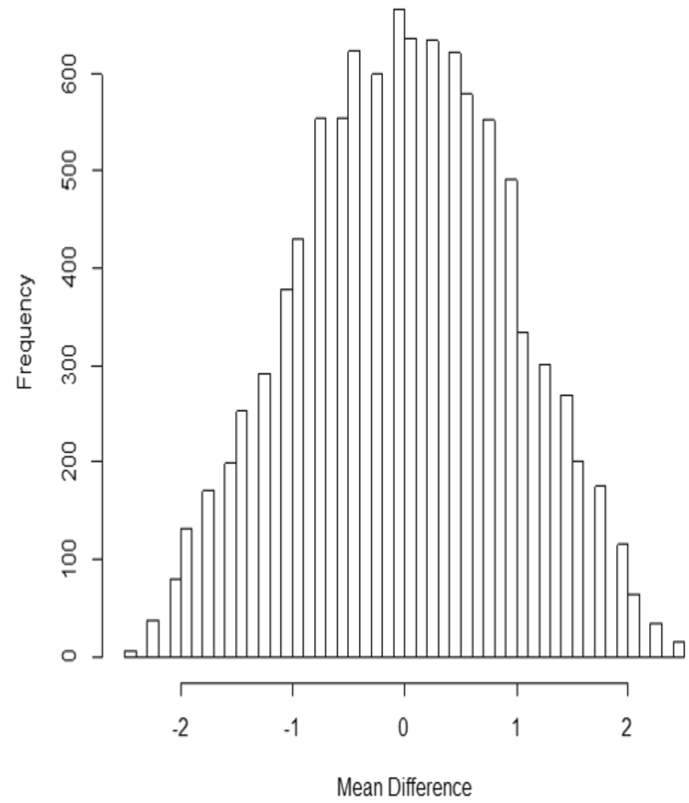


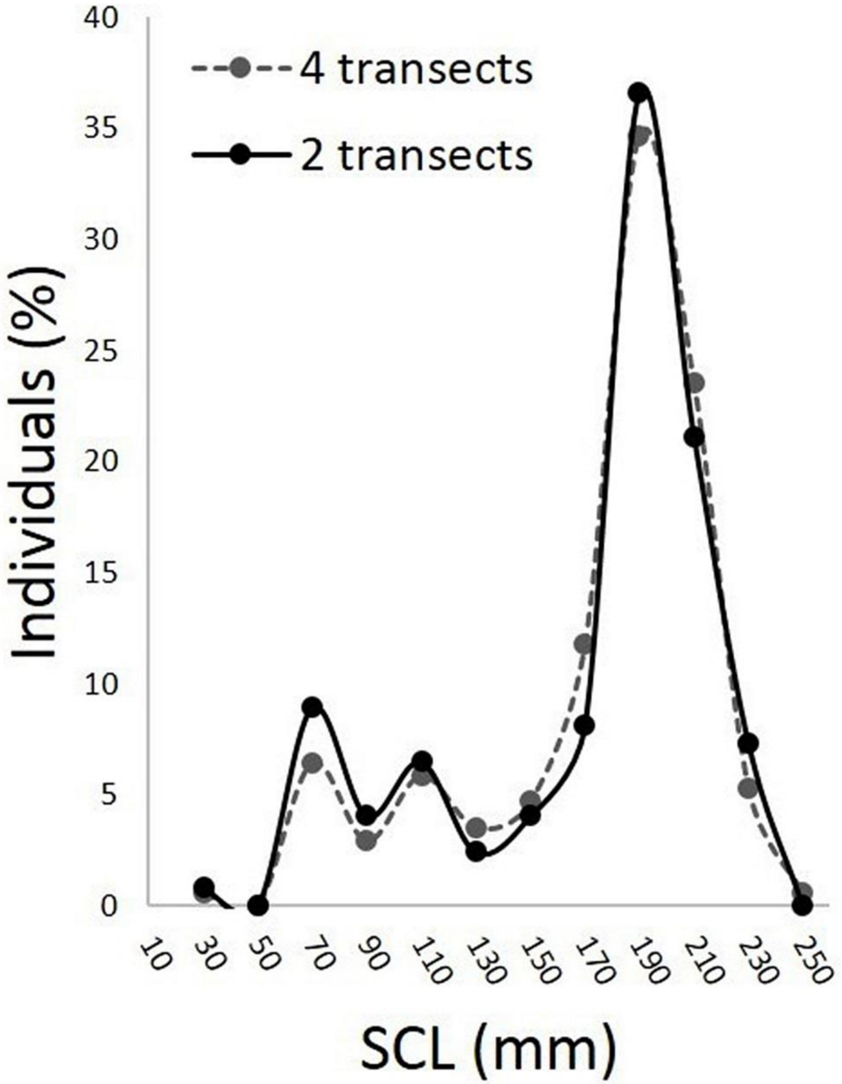
Other Considerations: Demography

- **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 Rohlff 1995)**
  - Paired sites randomized by transect sampling design

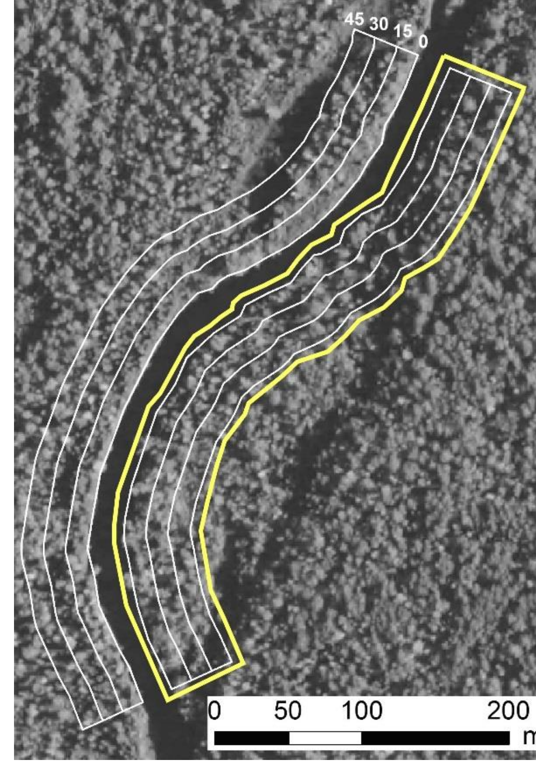


Results: Demography

- 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)

Site Code	Site	Sub-site (low)	*n* (low)	Sub-site (high)	*n* (high)
BO	4.6	2.0	1	5.9	3
CUT	7.7	5.9	3	7.9	4
GLN	6.6	0.0	0	8.4	5
IL	76.7	40.6	22	73.8	40
LG	36.4	26.4	14	30.2	16
NLG	9.9	3.6	2	9.1	5
SP	43.4	27.7	16	43.4	25
TR	62.2	40.8	23	62.1	35
Sum	247.5	147.0		240.8	

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: $z_i \sim Bernoulli(\psi)$
2. Observation process: $y_{ij}|z_i \sim Bernoulli(z_i p)$

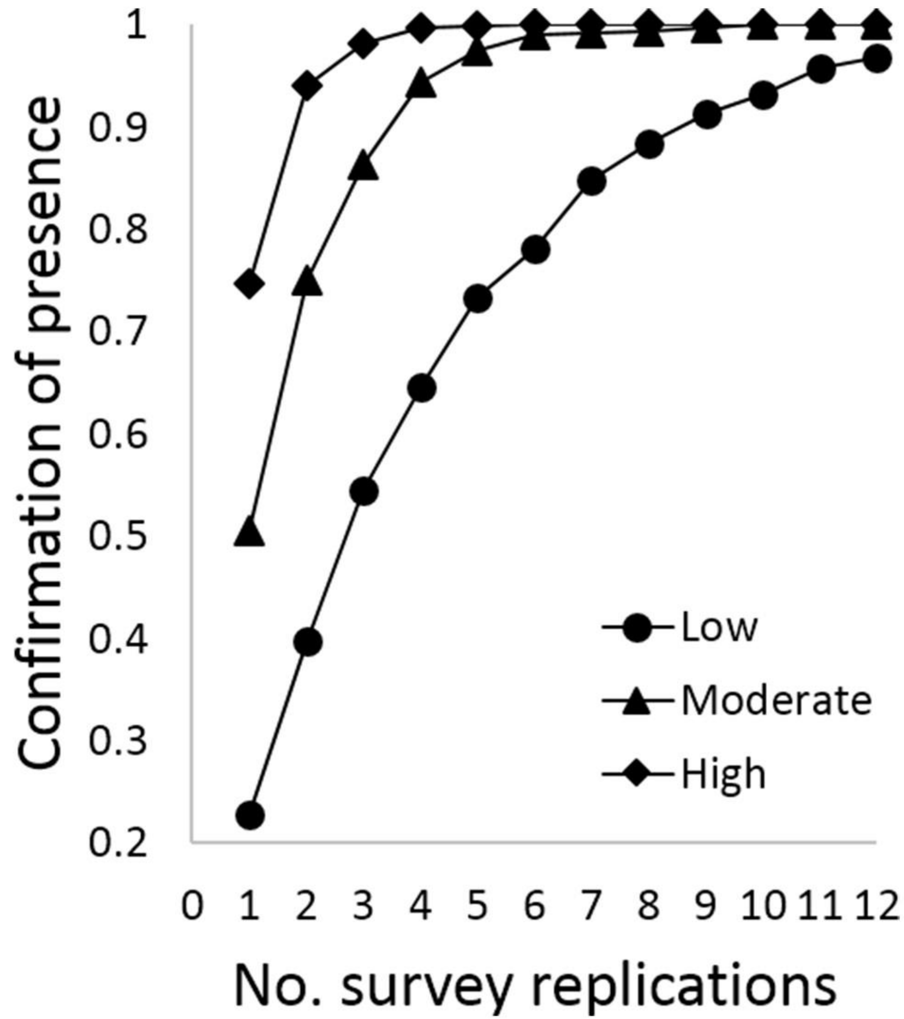
Methods/Results: Occupancy Surveys

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)

$$N_i \sim Poisson(\lambda_i), \text{with } \log(\lambda_i) = \beta_0 + \beta_1 * \text{vegHt}_i$$

This study

$$C_{ij}|N_i \sim Binomial(N_i, p_{ij}), \text{with } \text{logit}(p_{ij}) = \alpha_0 + \alpha_1 * \text{wind}_{ij}$$

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**

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

Jones, M. T., L. L. Willey, P. R. Sievert, and T. S. B. Akre. 2015. Status and conservation of the wood turtle in the northeastern United States. Final Report to the Regional Conservation Needs (RCN) Program. < http://rcngrants.org/sites/default/files/datasets/RCN2011-02v2.pdf >.

Acknowledgments

Funding

- Minnesota Department of Natural Resources (Grant #F14AP00028)
- University of Minnesota Integrated Biosciences Graduate Fellowship

Survey design discussions

- MNDNR: Carol Hall, Jeff Hines, Maya Hamady; WIDNR: Andrew Badje, Carly Lapin
- US Forest Service: Dan Ryan, Mark Nelson; Fond du Lac Reservation: Mike Schrage

Survey assistance

- K. Huston, C. Reno, A. Holleran, K. Goebel, J. Flory, M. Swingen, N. Ose

Additional Information

Publication:

Brown, D. J., M. M. Cochrane, and R. A. Moen. 2017. Survey and analysis design for wood turtle population monitoring. Journal of Wildlife Management: *In press*.

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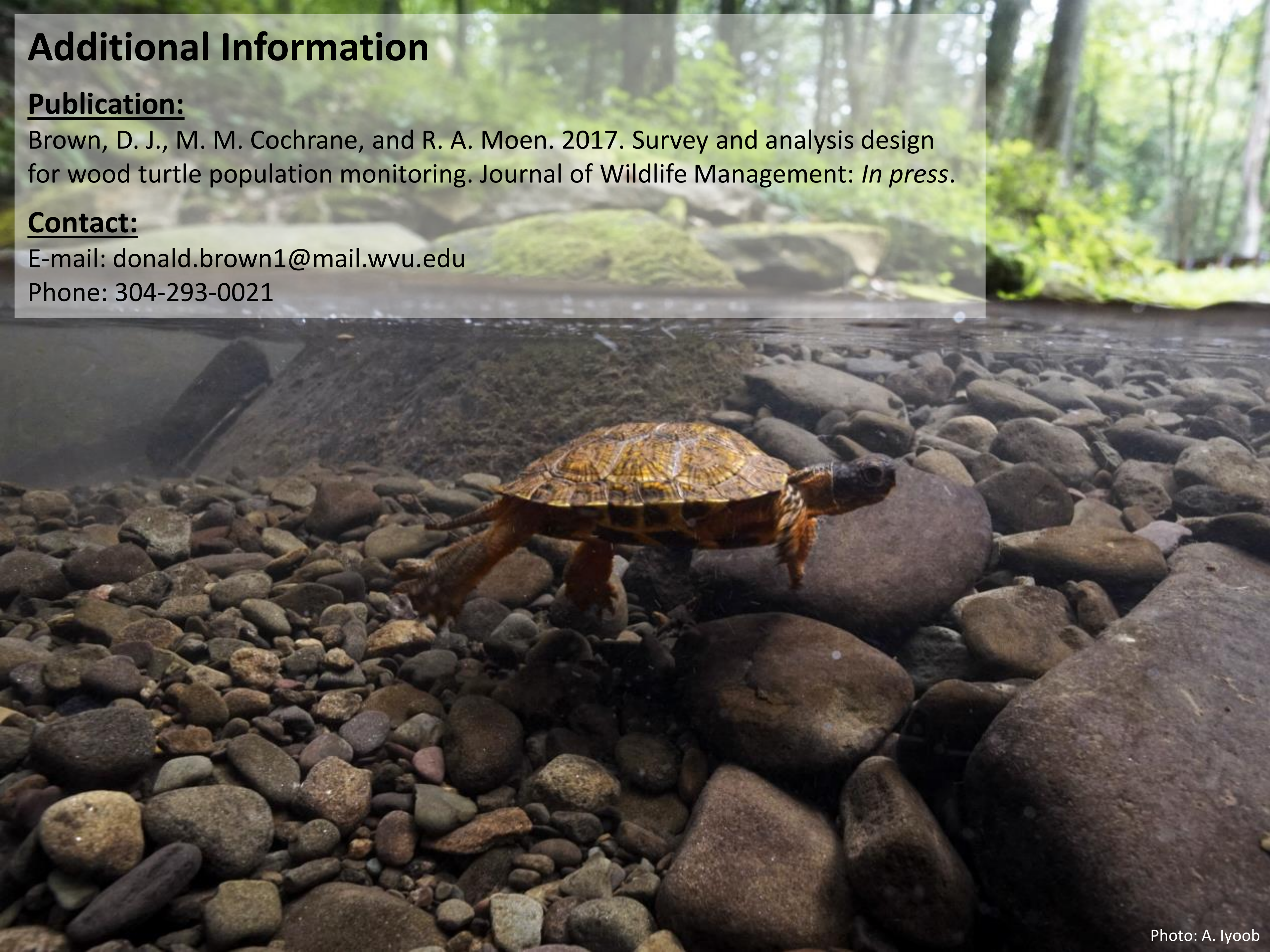

Photo: A. Iyoob