Award Number: F20AC00018

Project Code: FO-EWG-2147

Working Forests and Wood Turtles: Forest Management Effects on a Species of Conservation Concern

2023 Final Report

PROJECT CONTACTS

Michigan State University	Dr. Gary J. Roloff; roloff@msu.edu Tricia Brockman; brockm16@msu.edu
NCASI Foundation	Dr. Darren Miller; dmiller@ncasi.org
US Fish and Wildlife Service	Brad Potter; Bradley_Potter@fws.gov

BACKGROUND:

As part of the Wildlife Conservation Initiatives (WCI) mission, the US Fish and Wildlife Service (USFWS) and the National Alliance of Forest Owners (NAFO), in collaboration with the National Council for Air and Stream Improvement Foundation (NCASI Foundation), are using a proactive approach to better inform federal policies and best management practices related to species undergoing evaluation for listing under the Endangered Species Act of 1973 (called candidate species). The WCI identified North American wood turtle (*Glyptemys insculpta*, WOTU) as a candidate species negatively impacted by forest management but impacted in ways that can likely be mitigated or removed. This project aims to inform strategies for mitigating or removing threats to wood turtles, and for identifying conservation opportunities during forest management actions.

The USFWS and NCASI Foundation contracted with Michigan State University (MSU) to conduct research on the relationships between WOTU and private forest management in the western Upper Peninsula of Michigan. Specifically, this collaborative seeks to determine current occupancy status and spatial/temporal ecology of WOTU in NAFO owned and managed forests and relate occupancy status and land use to recent forest management practices (~15 years) and drainage basin condition. The objectives of this project were to 1) survey basins with historical WOTU occupancy records to determine current occupancy status, 2) survey additional proximate basins with no historical WOTU records, 3) parameterize detectability of WOTU in surveyed basins, 4) use VHF telemetry to determine the spatial /temporal ecology of female WOTU and refine detection and occupancy models, and 5) relate recent forest management and drainage basin conditions to WOTU occupancy status. We addressed these objectives in three thesis chapters 1) detection and occupancy, 2) movement and home range, and 3) resource selection. Our survey designs and vegetation sampling followed established protocols aimed at maximizing species detection and analyzing best management practices for forestry in the state of Michigan. In our fourth and final year of the project, we completed analysis on WOTU occupancy, seasonal movements and home range, and resource selection.

APPROACHES AND ACCOMPLISHMENTS:

Methods

Site selection
We initially chose 25 watershed basins (average size 9,111 ha) as replicates for occupancy surveys in the western Upper Peninsula of Michigan. These basins were selected based on historical records of WOTU occurrence, potentially suitable stream conditions for WOTU, containing at least some portion of NAFO managed land (ranged from 15 – 89% ownership in basins) preferably adjacent to flowing water, and where we would have river access either via NAFO, state or federal ownership. Three basins were rejected from these original 25 basins in 2020 for not meeting selection criteria. For the telemetry portion of this study, we focused on one basin in the northern portion of our study area and one in the southern portion of our study area. These basins were unique from each other in their topography, hydrology, vegetation, and recent management history.

Detection and Occupancy
For WOTU detection (*p*) and occupancy (Ψ) we used a visual encounter survey protocol developed by Brown et al. (2021). This protocol calls for surveyors to walk two parallel 1 km transects along each side of a river with one transect constrained to the riverbank and the second constrained to 15 m from the riverbank. We selected these 1 km segments using areal imagery to identify survey segments that contained exposed sandy banks that indicated possible WOTU nesting areas (i.e., where uplands were directly adjacent to the river), and where we had access through NAFO, state or federal lands. To maximize probability of detecting WOTU, we surveyed from beginning of May through late-June when WOTU are congregated near riverbanks before they disperse into uplands after nesting. During visual encounter surveys we recorded factors potentially affecting WOTU detection that included date, time, air temperature (°C), and water temperature (°C). We also collected information on factors that may affect WOTU occupancy like percent nesting substrate (sand and gravel), canopy cover and surrounding vegetation structure and composition. Upon detecting WOTU, we recorded age, sex, reproductive status, morphometrics, and behavior, and marked each WOTU with a unique ID number using shell notching.

For use in our detection and occupancy analysis, we summarized recent management history for each of our surveyed watershed basins using National Agriculture Imagery Program (NAIP) aerial imagery in Google Earth Engine. In each basin, we delineated an area within 400 m of each river (this distance reflected the maximum distance traveled by radio tagged female WOTU in our study). This area represented the spatial extent where active forest management could potentially most impact WOTU occupancy. We then generated Generalized Random Tessellation Stratified (GRTS) points within each 400 m buffer to ensure a spatially balanced sample. At each point we recorded forest management type (e.g., clearcut, thinning), approximate date of last canopy treatment, and ownership by analyzing a time series of NAIP imagery in Google Earth Engine starting in 2005 and ending in 2022, with a 2 – 4-year interval between each photo set. We used forest inventory data from NAFO member companies and the State of Michigan to validate our aerial imagery classifications.

We built our detection and occupancy models using unmarked package (Fiske and Chandler 2011) in program R. Our spatial replicates for estimating detection probability were each side of the 1 km survey segments along rivers. Hence, we estimated detection and occupancy probabilities at the 1 km river segment level. We assessed air and water temperature (°C), Julian date and survey effort as detection covariates and percent canopy cover, basal area, and available nesting substrate as occupancy covariates. Models were assessed using the dredge function from the MuMln function (Barton 2022), variance inflation factors (VIF) (Zuur et al. 2009) and candidate models ranked using Akaike information criterion (ΔAIC).

Movements and Home Ranges
To estimate seasonal movements and home ranges we affixed very high frequency (VHF) radio transmitters to 10 adult female WOTU in two basins; 5 in a northern basin and 5 in a southern basin. We chose female WOTU because, on average, female WOTU travel farther from flowing water than males, and may be affected more significantly by forest management activities (Brown et al. 2016). We relocated each WOTU 1-2 times per week from early May through end of September, with a minimum of two days between relocations to minimize disturbance. During relocation surveys we recorded the date, start and end time, air and water temperature. Upon relocating a turtle, we recorded the time, location, % canopy cover, % vegetation cover obscuring the WOTU, cover type, behavior, and any evidence of recent forest management in the vicinity. We also periodically palpated for eggs to determine reproductive status. We removed transmitters from nine WOTU in late September of 2022 and one in mid-May 2023.

To estimate seasonal movements of WOTU from the river, we calculated the mean weekly distance (m) of relocations from the river within each basin across individuals and years. Preliminary results suggested that still waterbodies (e.g., manmade ponds, seasonal pools, oxbow lakes) might influence WOTU movements in the southern basin, so we provided results with and without these waterbodies. We used a Mann-Whitney U Test to determine if there were significant differences in seasonal movement distances between basins.

We estimated individual home ranges by stream range and summer (i.e., terrestrial) range. We chose this approach to account for the two different movement strategies we observed during this study. Stream ranges were generally long, linear movements within the water course, and typically occurred for nesting or as WOTU prepared for over-wintering. Summer range represented the terrestrial space use of WOTU during the summer months. We estimated stream range by measuring the distance (m) between the two farthest relocation points along the path (i.e., not Euclidean distance) of the occupied river. We estimated summer home ranges by using relocations during the post-nesting season when WOTU are farthest from the river and used a 95% Brownian bridge kernel method from the adehabitatLT and adehabitatHR packages (Calenge 2006) in program R on these locations. We chose the Brownian bridge kernel method as it is best suited for estimating space use when relocations are spatially autocorrelated (i.e., subsequent relocations often near the prior location), which is a pattern we observed in our WOTU data. Stream range and summer home range were estimated for each individual and compared between years and basins using generalized linear mixed models (GLMM). Overlap of 95% summer home ranges was calculated for individuals tracked both years to test for site fidelity.

Resource Selection
For resource selection, we collected vegetation data at WOTU locations and compared environmental conditions at these WOTU points to randomly selected points in our telemetry watershed basins. To help ensure spatial independence between WOTU points, we used our 2021 relocation data to create kernel density maps for each turtle. We then calculated the mean diameter of the 5% use area (i.e., core use area) for each WOTU, which was 25m. We only collected environmental data on WOTU points separated by 25m or more. Additionally, we removed relocation points falling within flowing water. We paired our 2022 telemetered WOTU locations with GRTS points within 400m of flowing water. At each point (WOTU and random) we used a 20 x 5 m belt transect to assess % canopy cover, basal area, shrub stem density, distance to haul roads, and recent forest management activity.

Preliminary Results (currently being finalized in an MS Thesis by T. Brockman)

Detection and Occupancy

During our study we completed surveys in 12 basins, partially surveyed four basins and did not survey six basins that were part of our original experimental design. We missed the six basins because of field logistics; travel time and other duties (e.g., relocating WOTU once telemetered took precedence over surveys. We detected WOTU in five basins, three with historic occupancy records (Table 1). We detected and marked 29 WOTU (11 females, 10 males, and 8 juveniles) during surveys, detected and marked 37 WOTU (18 females, 13 males and 6 juveniles) out of survey, detected but were unable to mark 6 WOTU, and detected 5 WOTU outside of our study area. Eight WOTU were reported by foresters from NAFO member organizations (Table 1).

Table 1. WOTU detections from 2020 - 2022 by survey basin. H indicates basins with historical records and C indicates basins in which surveys have been completed.

Basins Surveyed	WOTU Detected in Survey	WOTU Detected Out of Survey (marked)	WOTU Detected Out of Survey (unmarked)	NAFO Forester Reports	**Total WOTU Detected per Basin**
EBFR (C)	0	0	0	0	**0**
EBHR (C)	0	0	0	0	**0**
EBNR	0	0	0	0	**0**
EBSR (C)	0	0	0	0	**0**
HCSR (H/C)	7	23	4	0	**34**
LWBR (H)	0	0	0	1	**1**
PCCR (H/C)	0	0	0	0	**0**
PERR (H/C)	4	1	0	0	**5**
SILR (C)	2	0	0	0	**2**
SLAR (C)	0	0	0	0	**0**
TNFR (H/C)	8	13	2	2	**25**
WBCR (C)	0	0	0	0	**0**
WBFR (H)	0	0	0	0	**0**
WBHR (C)	8	0	0	0	**8**
WEHR	0	0	0	0	**0**
WFRR (C)	0	0	0	0	**0**
Other	NA	NA	5	5	**10**
Total WOTU Detected	**29**	**37**	**11**	**8**	**85**

For our detection and occupancy models we used survey data from 15 basins, four of which were occupied. Most basins had three spatial replicates (i.e., 1-km stream segments surveyed on both sides). The model with the most support for predicting segment-level occupancy included Julian date (β= -2.86, SE = 2.49) and air temperature at the start of each survey (β = -2.19, SE = 2.18) as detection (*p)* covariates, and percent nesting substrate for occupancy (Ψ) (β = 1.04. SE = 0.61) (Table 2, Figure 1). Of the candidate model set, the top-ranking model received ~38% of the support (Table 2). An additional model that included canopy cover was identified as competing (i.e., within 2 ΔAIC; Table 2), but the effect size for canopy cover was negligible. We continue to explore relationships between recent forest management history within 400 m of segments.

Table 2. Akaike information criterion (ΔAIC) ranking of ccupancy (Ψ) models built using unmarked package (Fiske and Chandler 2011) to help predict wood turtle occupancy along 1 km river segments in the western Upper Peninsula of Michigan. Detection (*p* covariates are Julian date (Date) and the air temperature (C) (AirStart) at survey start. Ψ covariates are proportion nesting substrate (sand and gravel) (NestSub), percent canopy cover (CanCov) and basal area (BasalArea) of woody species present along the river bank.

p	Ψ	ΔAIC	df	weight
Date + AirStart	NestSub	0.0	5	0.383
Date + AirStart	NestSub + CanCov	1.7	6	0.166
Date + AirStart	NestSub + BasalArea	2.0	6	0.144
Date + AirStart	NestSub + BasalArea + CanCov	2.7	7	0.098
Date + AirStart	CanCov	3.6	5	0.065

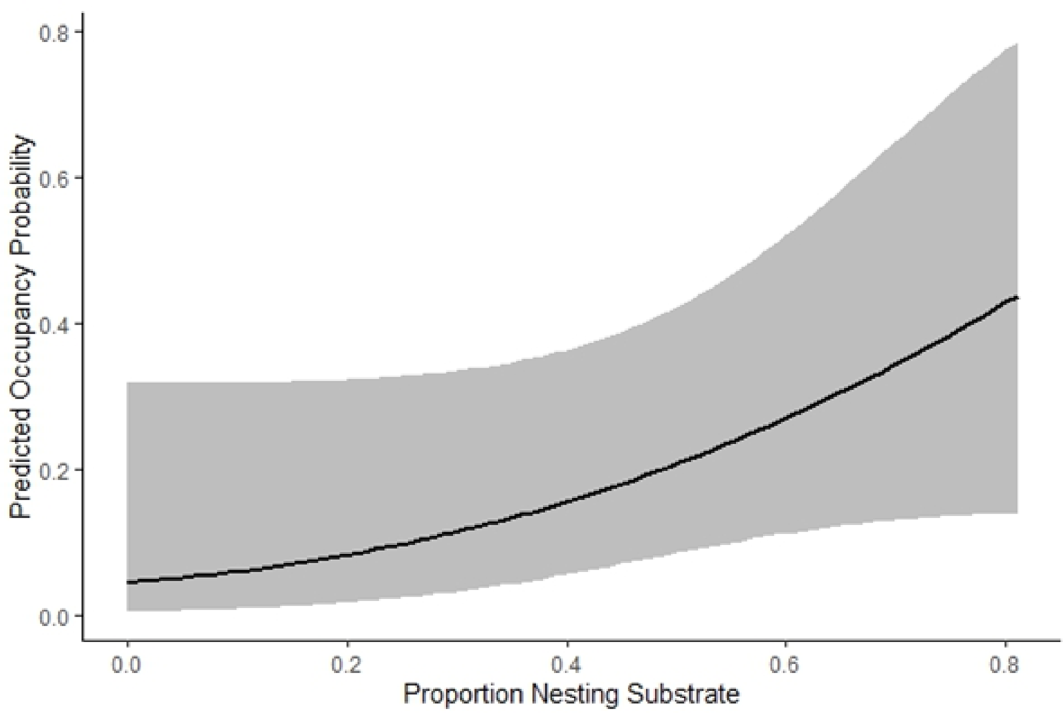

Fig. 1. Predicted occupancy (Ψ) probability of 1 km river segments based on the proportion of nesting substrate (sand and gravel) making up the bank substrate in the western Upper Peninsula of Michigan. The grey band represents 95% confidence intervals.

Movements and Home Ranges

WOTU in north and south basins were relocated closest to the river during the pre-nesting (early May - early June) ($\bar{x}$ = 30.3m, SE = 8.5, range = 0m - 183.9m) and pre-brumation (mid-September - late October) ($\bar{x}$ = 6.0m, SE = 4.4, range = 0m - 58.9m) activity periods, and farthest from the river during the nesting (mid- - late June) ($\bar{x}$ = 90.7m, SE = 16.0m, range = 0m - 381.6m) and post-nesting (early July - mid-September) ($\bar{x}$ = 143.2m, SE = 5.4, range = 0m - 373.0m). Mean weekly distances from the river between basins indicated that female WOTU relocations in the southern basin tended to occur farther from the river than those in the northern basin during the pre-nesting and early nesting periods (Figure 2A). When still waterbodies were incorporated into the analysis, distances appeared more similar between basins (Figure 2B). A Mann-Whitney U Test indicated that average WOTU distance from the river between basins differed only during post-nesting (w = 7, *P* value = 0.03), with marginal support for differences in pre-nesting and nesting (Table 3). We note that 95% of all WOTU relocations were within 326.3m of the occupied river and 238.0m of all waterbodies found within 400m of the river.

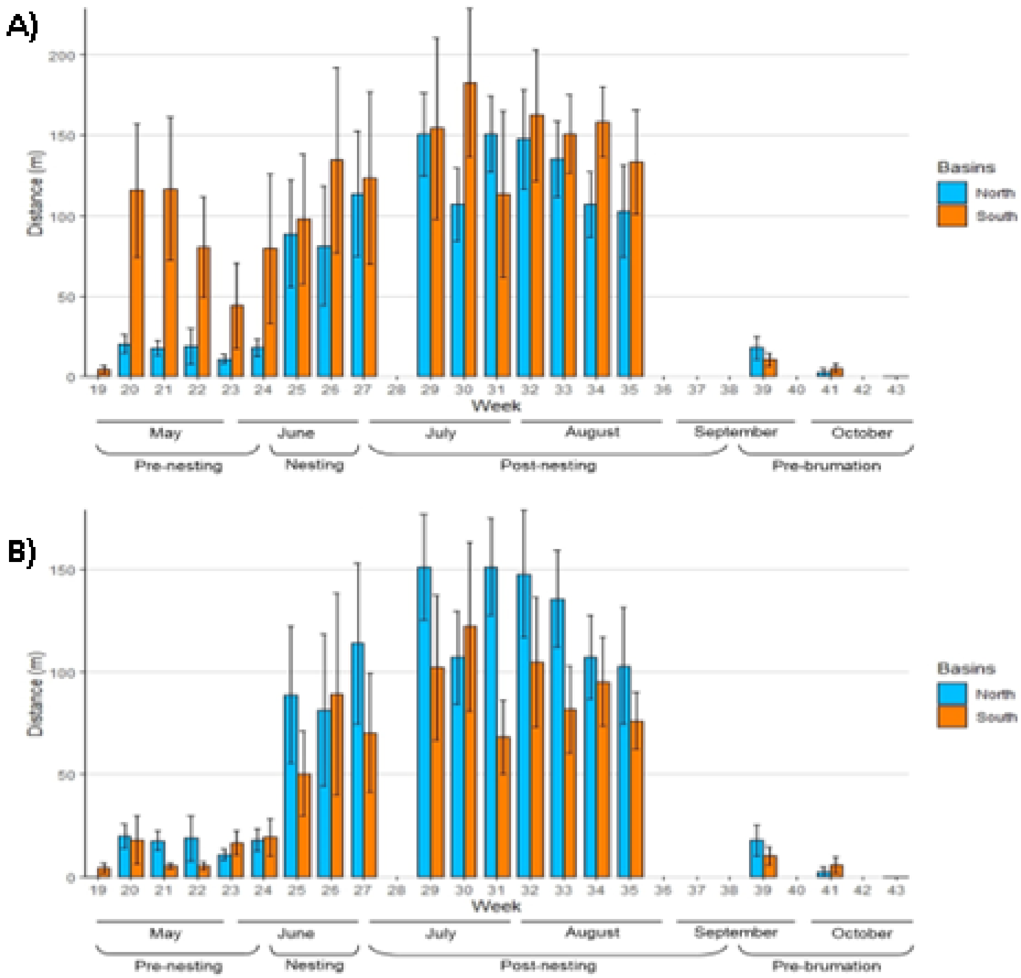

Fig. 2. Mean weekly distances (m) and standard errors of adult female wood turtle (WOTU) relocations from the river (**A**) and from all waterbodies (**B**) in two watershed basins in the western Upper Peninsula of Michigan. Five WOTU in each basin were relocated 1 - 2 times per week through the 2021 and 2022 active seasons (May - October). There appears to be a disparity between basins during the pre-nesting and early nesting activity periods, where WOTU relocations were farther from the river in the southern basin. When mean weekly distances were calculated from all waterbodies, they appeared more similar.

Table 3. Results of a Mann-Whitney U Test comparing the mean weekly distance (m) of adult female wood turtle (WOTU) relocations from the river by activity period between two watershed basins in the western Upper Peninsula of Michigan. Five WOTU in each basin were relocated 1 - 2 times per week, through the 2021 and 2022 active seasons (May - October). The only significant difference detected by the test was during the post-nesting period.

Activity period	w	*P* value
Pre-nesting	4	0.09
Nesting	2	0.11
Post-nesting	7	0.03
Pre-brumation	4.5	1.00

Mean stream range in the northern basin was 3,786.7m (SE = 947.3m, range = 674.7m – 7,190.5m) and 1,127.8m (SE = 518.9m, range = 0 – 5,863.2m) in the southern basin (Figure 3A). Mean 95% summer home range was 3.58ha (SE = 0.75, range = 0.28 - 7.01ha) in the north and 2.53ha (SE = 0.78, range = 0.86 - 5.08ha) in the south (Figure 3B). We found no significant difference in stream range or 95% summer home range sizes between basins or years. Overlap between summer home ranges for WOTU tracked both years was 70.6% (SE = 7.54, range = 43.32 - 95.96%) indicating a relatively high degree of site fidelity.

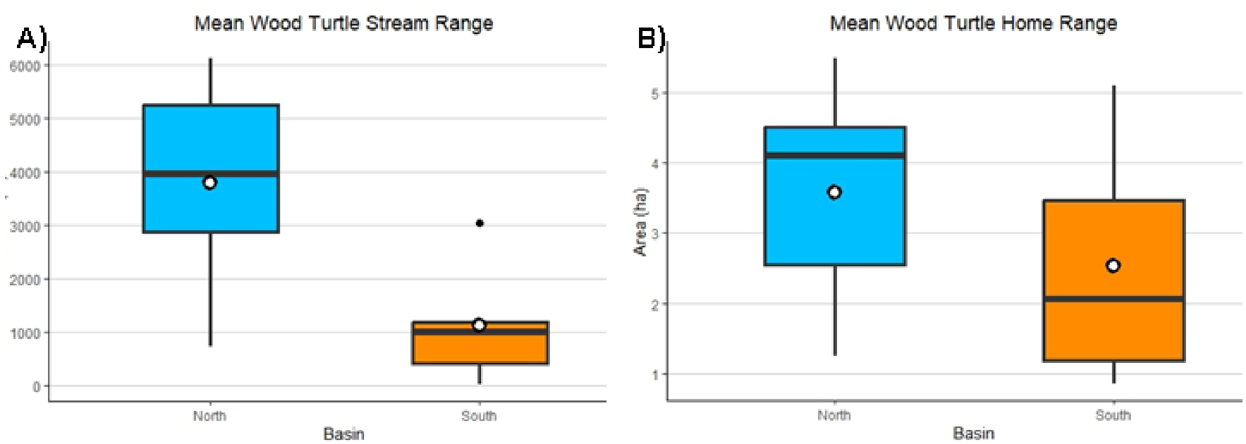

Fig. 3. Stream range (**A**) and 95% summer home range (**B**) for adult female wood turtles (WOTU) in two watershed basins in the western Upper Peninsula of Michigan. Five WOTU were in each basin tracked from May - October of 2021 and 2022. Stream range was calculated by measuring the distance (m) along the rivers path between the two farthest relocations for each individual per year. 95% summer home range size (ha) was calculated using the Brownian bridge kernel method for relocations isolated during the post-nesting activity period. Boxplots of the data include the mean values (white centered circle) appear to show a significant difference in stream range size. A GLMM indicated that there were no significant differences between basins.

Resource Selection

Analyses of resource selection are ongoing, so we offer preliminary impressions. Female WOTU appeared to select areas with lower basal area, though within the range of available basal areas in each basin. Canopy cover differed between basins with a higher percentage in the northern basin than the southern basin. However, WOTU in both basins selected areas with similar intermediate canopy cover. We observed all female WOTU using a variety of managed forest cover types including a 12-year-old white pine shelterwood, 8- and 20-year-old regenerating aspen clearcuts, a 27-year-old larch plantation, 18-year-old hardwood select cut, and a 2-year-old hardwood shelterwood. WOTU often utilized anthropogenic features resulting from management, like slash piles, utility easements, gravel pits and decommissioned haul roads.

Preliminary Management Recommendations

- Conducting visual encounter surveys during April and May using the protocol by Brown et al. (2021) is an effective way to confirm occupancy. Survey locations can be chosen by identifying sections of river with areas of exposed sand and gravel along the banks from aerial imagery.
- Seasonal management buffers (see below) restricting machine intensive harvests should be utilized along a rivers course on either side of a wood turtle observation. The length of these buffers depends heavily on spatial arrangement of nesting sites. These distances can average 4,000m in areas with sparse nesting opportunity (e.g., our northern basin) to 1,000m in areas where nesting substrate is more readily available (e.g., our southern basin).
- Buffers should be utilized on either side of occupied river sections. Minimum buffer distance recommendations are based off distances from the river that encompassed 95% of our turtle relocations in the northern basin.
    - April - May - 60 m (197 ft)
    - June - August - 250 m (820 ft)
    - September - October - 60 m (197 ft)
    - No buffer needed if there is snow cover
- Slash and other debris retained on the landscape as a source of cover and basking.
- Close old haul roads to vehicle use after harvest is complete.

Outreach

During the summers of 2021 and 2022, we engaged 74 foresters from five NAFO member organizations through 7 workshops focusing on wood turtle ecology and conservation. These workshops were held either in-person or virtually. In-person workshops usually included both an office and field component. Organizations engaged were American Forest Management, Lyme Great Lakes Timberland, Manulife Investment Management, Molpus Woodlands Group, and Potlatch Deltic.

TARGET COMPLETION DATE: Dec 2023

PROJECT BUDGET TO DATE:

April 2020-March 2021 - $65,034 from NCASI Foundation
April 2021-March 2022 - $81,042 from NCASI Foundation
April 2022-March 2023 - $69,685 from NCASI Foundation
April 2023-March 2024 - $23,421 from NCASI Foundation

EXPECTED OUTPUTS:

1) Basin-specific occupancy status for WOTU.
2) GIS layers depicting at least 15 years of forest management and other activities in each basin; relate these activities to occupancy probability.
3) Parameterized occupancy models for WOTU, with a focus on using variables from remote-sensing or standard forest inventory techniques.
4) Summary of WOTU spatial ecology.
5) Describe project results through thesis, peer-reviewed publications, and engagement with collaborators or interested stakeholders.

LITERATURE CITED:

Barton, K. 2023. Package MuMIn (Multo-Model Inference). R Programming Language.

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.

Brown, D. J., M. T. Jones, and A. Beard. 2021. Wood turtle survey design comparison. Unpublished report.

Calenge, C. 2006. The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modelling 197:516-519.

Fiske, I., and R. Chandler. 2011. unmarked: An R Package for fitting hierarchical models of wildlife occurrence and abundance. Journal of Statistical Software 43(10): 1-23.

Zuur, A.F., E.N. Ieno, N. Walker, A.A. Saveliev, G.M. Smith. 2009. Mixed effects models and extensions in ecology with R. Springer.

WORKSHOPS:

Brockman, T. G., B. A. Potter, D. A. Miller, and G. J. Roloff. Working Forests and Wood Turtles: Effects of Forest Management on a Species of Conservation Concern. Wood Turtle Workshop, Lyme Great Lakes Timberlands, L'Anse, MI. June 23, 2021.

Brockman, T. G., B. A. Potter, D. A. Miller, and G. J. Roloff. Working Forests and Wood Turtles: Effects of Forest Management on a Species of Conservation Concern. Wood Turtle Workshop, Lyme Great Lakes Timberlands, L'Anse, MI. June 30, 2021.

Brockman, T. G., B. A. Potter, D. A. Miller, and G. J. Roloff. Working Forests and Wood Turtles: Effects of Forest Management on a Species of Conservation Concern. Wood Turtle Workshop, Molpus Woodlands Group, Houghton, MI. July 21, 2021.

Brockman, T. G., B. A. Potter, D. A. Miller, Steven M. Gray, and G. J. Roloff. Working Forests and Wood Turtles. Wood Turtle Workshop, American Forest Management, Houghton, MI. July 11, 2022. (Office and field)

Brockman, T. G., B. A. Potter, D. A. Miller, Steven M. Gray, and G. J. Roloff. Working Forests and Wood Turtles. Wood Turtle Workshop, Lyme Great Lakes Timberland, Arnold, MI. August 2, 2022. (Field only)

Brockman, T. G., B. A. Potter, D. A. Miller, Steven M. Gray, and G. J. Roloff. Working Forests and Wood Turtles. Wood Turtle Workshop, Manulife Investment Management, Virtual. August 16, 2022. (Virtual)

Brockman, T. G., B. A. Potter, D. A. Miller, Steven M. Gray, and G. J. Roloff. Working Forests and Wood Turtles. Wood Turtle Workshop, Potlatch Deltic, Gwinn, MI. August 18, 2022. (Office only)