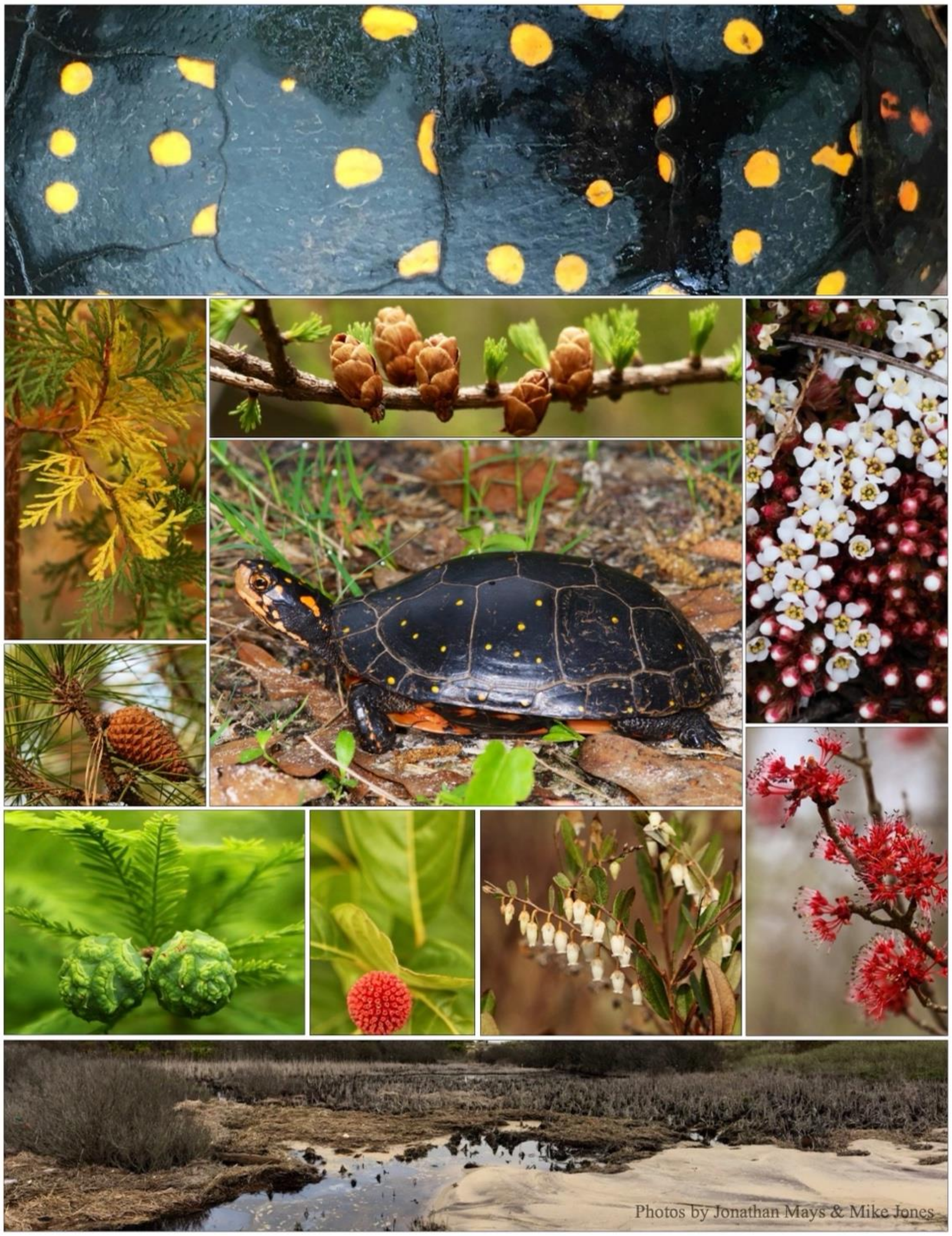
STATUS ASSESSMENT AND CONSERVATION PLAN for the SPOTTED TURTLE in the EASTERN UNITED STATES

Maine • New Hampshire • Vermont • Massachusetts • Connecticut • Rhode Island • New York • New Jersey • Pennsylvania • Delaware • Maryland • DC • Virginia • West Virginia • North Carolina • South Carolina • Georgia • Florida



Photos by Jonathan Mays & Mike Jones

Final Report
submitted to the Virginia Department of Wildlife Resources, the Northeast Association of Fish and Wildlife Agencies, and the U.S. Fish and Wildlife Service

for the Competitive State Wildlife Grant: Conservation and Management of the Spotted Turtle (*Clemmys guttata*) and Associated SGCN on the Atlantic Coastal Plain and Adjacent Piedmont Ecoregions

September 2022

Status Assessment and Conservation Plan for the Spotted Turtle in the Eastern United States

October 13, 2022

Edited by:
Lisabeth L. Willey and Molly K. Parren
Antioch University New England
American Turtle Observatory

Michael T. Jones
Massachusetts Division of Fisheries and Wildlife

With contributions from:

H. Patrick Roberts
University of Massachusetts Amherst

Jessica R. Meck and Thomas S.B. Akre
Smithsonian Conservation Biology Institute

John D. Kleopfer
Virginia Department of Wildlife Resources

Lori Erb
The Mid-Atlantic Center for Herpetology and Conservation

Houston C. Chandler
The Orianne Society

John Garrison, Cullen Mackenzie, Nadya Bennett, Savannah Kerns, and Kathryn Lauer
Antioch University New England
American Turtle Observatory

Donald J. Brown and Joel L. Mota
West Virginia University

Katharine Gipe
Pennsylvania Fish and Boat Commission

Eric B. Liebgold and Tami S. Ransom
Salisbury University

Phillip deMaynadier and Derek Yorks
Maine Department of Inland Fisheries and Wildlife

Jonathan Mays
Florida Fish and Wildlife Conservation Commission

Scott Buchanan
Rhode Island Dept. of Environmental Management

Jeff Hall
North Carolina Wildlife Resources Commission

Nathan H. Nazdrowicz
Delaware Division of Fish & Wildlife

Kevin J. Oxenrider
West Virginia Division of Natural Resources

Brian Zarate
New Jersey Division of Fish and Wildlife

Scott Smith
Maryland Department of Natural Resources

Melissa Winters and Joshua Megyesy
New Hampshire Fish and Game Department

Lindsay Rohrbaugh
District of Columbia Department of Energy & Environment

Prepared for:
Virginia Department of Wildlife Resources
U.S. Fish and Wildlife Service
Northeast Association of Fish and Wildlife Agencies

Supported by State Wildlife Grants through the Competitive State Wildlife Grants and the Northeast Regional Conservation Needs (RCN) Programs

Recommended citation: Willey, L.L., M.K. Parren, and M.T. Jones (eds.). 2022. Status Assessment and Conservation Plan for Spotted Turtles in the Eastern United States. Technical Report to the Virginia Dept. of Wildlife Resources and the U.S. Fish and Wildlife Service.

An electronic version of this report, as well as Appendices, supporting documentation, and resources, is located online at: **http://northeastturtles.org**

Cover photographs by Jonathan Mays (FWC) and Mike Jones (MassWildlife)

Members of the Eastern Spotted Turtle Working Group

Angelena Ross, New York State Dept. of Conservation and Recreation
Brandon Ruhe, The Mid-Atlantic Center for Herpetology and Conservation
Brian Zarate, New Jersey Division of Fish and Wildlife
Chris Urban, Pennsylvania Fish and Boat Commission
Derek Yorks, Maine Department of Inland Fisheries and Wildlife
Donald J. Brown, West Virginia University
Ellery Lassiter, University of Illinois Urbana-Champaign
Eric B. Liebgold, Salisbury University
Glenn Johnson, State University of New York, Potsdam
H. Patrick Roberts, University of Massachusetts Amherst
Holly Niederriter, Delaware Department of Natural Resources and Environmental Control
Houston C. Chandler, The Orianne Society
Jeff Hall, North Carolina Wildlife Resources Commission
Jessica R. Meck, Smithsonian Conservation Biology Institute
Joel Mota, West Virginia University
John D. Kleopfer, Virginia Department of Wildlife Resources
John Garrison, Antioch University New England / American Turtle Observatory
Joshua Megyesy, New Hampshire Fish and Game Department
Jonathan Mays, Florida Fish and Wildlife Conservation Commission
Julie A. Slacum, U.S. Fish and Wildlife Service
Katharine Gipe, Pennsylvania Fish and Boat Commission
Kevin Oxenrider, West Virginia Division of Natural Resources
Lindsay Rohrbaugh, DC Department of Energy & Environment
Lisabeth L. Willey, Antioch University New England / American Turtle Observatory
Lori Erb, The Mid-Atlantic Center for Herpetology and Conservation
Luke Groff, Vermont Fish and Wildlife Department
Melissa Winters, New Hampshire Fish and Game Department
Michael J. Ravesi, Connecticut Department of Energy and Environmental Protection
Michael T. Jones, Massachusetts Division of Fisheries and Wildlife
Michelle Fonda, West Virginia Division of Natural Resources
Molly K. Parren, Antioch University New England / American Turtle Observatory
Nathan Nazdrowicz, Delaware Dept. of Natural Resources and Environmental Control
Paul Novak, New York State Dept. of Environmental Conservation
Phillip deMaynadier, Maine Department of Inland Fisheries and Wildlife
Rodney Dyer, Virginia Commonwealth University
Scott Buchanan, Rhode Island Dept. of Environmental Management
Scott Smith, Maryland Dept. of Natural Resources
Thomas S.B. Akre, Smithsonian Conservation Biology Institute

Table of Contents

Acknowledgments

This project began in earnest through discussions at Northeast Partners in Amphibian and Reptile Conservation (NEPARC) meetings in 2013, 2014, and 2015—initially as a concept for a Northeast Association of Fish and Wildlife Agencies (NEAFWA) Regional Conservation Needs (RCN) grant, and later a Competitive State Wildlife Grant (C-SWG) project. Ultimately, the Spotted Turtle Working Group formed within NEPARC in 2016 and built on a model of previous regional conservation planning efforts for Blanding's Turtles, Wood Turtles, and Bog Turtles. Indeed, the regional Partners for Amphibian and Reptile Conservation (PARC) meetings provided a critical framework for planning discussions and networking.

The planning and sampling elements of this project were supported in part by a C-SWG (F18AP00182) awarded to Virginia Department of Wildlife Resources and partner agencies from Maine to Florida, as well an RCN Grant (rcngrants.org) that specifically supported a conservation genetics component and field studies in five states that did not receive C-SWG funds. Funding for field sampling in South Carolina was provided by the U.S. Fish and Wildlife Service (USFWS) Ecological Services, Coastal Program to the Orianne Society (F15AC00965 Modification 3). USFWS Northeast Region's Science Applications Program supported sampling in North Carolina and additional genetic analyses. Sampling on Department of Defense (DoD) Installations was supported via the DoD Legacy Natural Resource Management Program and DoD PARC.

We gratefully acknowledge the support of the home institutions of the members of the Spotted Turtle Working Group, as well as state wildlife agencies that supported the undertaking of this project via administrative support and permitting. Additionally, H. Patrick Roberts was partially supported by a Natural Resources Conservation Service grant award (NR193A750023C003).

Many state wildlife agencies, public and private universities, non-governmental organizations, and individuals supported this project in critical ways. Natural Heritage programs throughout the region graciously provided Spotted Turtle element occurrence data, and HerpMapper and the Global Biodiversity Information Facility (GBIF) provided additional key data. Dee Blanton, Julie Slacum, Laura Eaton, and Anthony Tur of the U.S. Fish and Wildlife Service provided advice and support throughout the process, and Christopher Petersen and Robert Lovich provided support for efforts on DoD lands.

We wish to acknowledge the many biologists who led field-sampling efforts or otherwise provided field support, including: L. Anne, J. Arnold, B. Battistella, J. Bittner, A. Blair, W. Blair, M. Blance, C. Bortz, M. Bottini, J. Bourne, R. Bowers, R. Brandon, J. Briggs, D. Canning, Z. Cava, R. Chirumble, P. Cicchetti, E. Claggett, D. Conley, S. Cooke, L. Corcoran, J. Cramer, L. Cruz, N. Curtis, T. Curtis, H. Dallas, J. Dell, G. DeMellion, J. Derr, J. Dominguez, J. Duvall, L. Eaton, M. Elliot, B. Emanuel, A. Fisher, H. Floyd, S. Fox-Trudeau, L. Franzluebbers, B. Furlong, S. Gillen, T. Gingrich, S. Giordano, E. Glitzenstein, A. Grosse, A. Gulette, C. Guy, T. Hackemack, M. Hagaman, A. Haines,

T. Hall, N. Hallisey, E. Hamel, S. Hartzell, C. Hauer, R. Healey, B. Heres, P. Hess, M. Holden, K. Horwitz, L. Howard, B. Hunt, D. Hunt, D. Hutto, C. Innis, A. Jarboe, K. Jennings, J. Johnson, K. Johnson, L. Johnson, M. Johnstone, J. Kessler, S. Koch, S. Lefoley, K. Leonard, A. Litterer, G. Madden, N. Madden, M. Malone, V. Malzone, C. Manning, K. Marden, T. Maret, R. Mason, J. McCumber, D. McNaughton, S. Millman, P. Moler, E. Molleen, D. Moore, I. Moore, J. Moore, M. Morrison, R. Nagel, E. Nichols, P. Novak, L. Olson, D. Paulson, T. Persons, A. Pertoz, R. Picone, J. Piscitelli, J. Potter, T. Pluto, N. Rampersand, K. Reshetiloff, E. Robertson, M. Rothrock, T. Russell, J. Sagner, C. Scott, B. Settele, J. Shinskie, M. Siefert, E. Sikora, N. Simmons, H. Small, A. Smith, J. Smith, P. Smithson, A. Stauffer, D. Steen, B. Stegenga, D. Stevenson, C. Titus, B. Tornwall, H. Trowbridge, A. VanVorst, N. Vermeulen, E. VonBoeckman, T. Wantman, S. Ward, R. Wataha, R. Watkins, M. Whitbeck, C. White, J. White, B. Williams, J. Wolfgang, R. Yurchisin, and L. Ziemba.

We also wish to thank the many landowners (individuals and organizations) that allowed access to their land for surveys, trapping, and habitat management. Among many state, federal, and non-governmental organizations, we wish to specifically acknowledge the U.S. Fish and Wildlife Service's National Wildlife Refuges, the National Park Service, and Department of Defense installation partners.

In June 2021 the Spotted Turtle Working Group and the northeastern conservation community lost Dr. Peter Rosenbaum, professor emeritus at the State University of New York (SUNY) Oswego. Peter dedicated a substantial portion of his career to the study and conservation of Bog Turtles, Spotted Turtles, and other New York herpetofauna. Peter's legacy lives on through his students and the wetland study areas he worked hard to conserve.

Executive Summary

The Spotted Turtle (*Clemmys guttata*) occurs in a wide variety of shallow and seasonal freshwater wetlands throughout eastern North America from eastern Maine to north-central Florida. As with related species in the subfamily Emydinae, Spotted Turtles' late maturity, small size (and limited reproductive capacity) and frequent terrestrial habitat-use leave them vulnerable to anthropogenic conversion of wetlands and certain intensive land uses (notably, residential development and urbanization). Spotted Turtles are classified globally as Endangered by the IUCN and Endangered in Canada. They are also listed as Endangered in three states, Threatened or Special Concern in five states, and are designated a Regional Species of Greatest Conservation Need (RSGCN) in the northeastern United States.

Concern for the status of the species has been widespread and protracted. As a result, the eastern range states from Maine to Florida partnered in 2016 to undertake a collaborative status assessment and conservation planning process for the species. As the core of that effort, we: (1) compiled occurrence records from varied sources to delineate sites regionwide; (2) undertook a standardized sampling program; (3) evaluated species status (including threats) using quantitative metrics; (4) ranked delineated sites based upon analyses of landscape and population data; and (5) developed a conservation action plan to track, guide, and prioritize future management actions. This Status Assessment and Conservation Plan represents the culmination of that multi-year collaboration and follows the approach taken for related turtle species in the northeastern United States. In a complementary funding arrangement, this project was supported by a Competitive State Wildlife Grant to the Virginia Department of Wildlife Resources and partner agencies throughout the eastern United States, and a Regional Conservation Needs grant from the Northeast Association of Fish and Wildlife Agencies, as well as the partnering state wildlife agencies.

The document is arranged in six parts. In Part I, we provide an overview of relevant aspects of the species' ecology, threats, status, and management. In Part II, we assess the distribution of the species through the compilation of occurrence records, delineation of sites, and modeling of suitable habitat. In Part III, we detail the standardized population assessments undertaken throughout the region. In Part IV, we evaluate and analyze the influence of environmental change on population viability (particularly land-use and climate change). In Part V, we propose a spatially explicit Conservation Area Network (CAN) consisting of stratified and ranked high-priority sites throughout the region. In Part VI, we outline a Conservation Action Plan (CAP) designed to conserve representative and resilient, self-sustaining populations of Spotted Turtles throughout their range in the eastern United States. Core components from each part are summarized the following sections.

Delineation of Spotted Turtle Sites

We compiled 11,957 Spotted Turtle occurrence records from across the eastern United States, including both current and historical (i.e., older than 1990; n=605) records. To delineate sites, we buffered each Spotted Turtle record by 500 m. Adjacent suitable wetlands (freshwater emergent and forested/shrub) were selected and buffered by 200 m to include adjacent upland habitat.

This process resulted in the delineation of 2,351 sites comprising 769,080 ha of delineated habitat. The average delineated site is based on 5.2 records and is 327.5 ha in size. Within sites, 19.6% of the area comprises wetlands, 8.0% is agriculture, and 16.2% is impervious surface cover. The majority (61%) and the greatest density of sites are located along the Coastal Plain ecoregion from coastal New England to coastal Virginia, with fewer delineated sites (4.3%) in the Southern Coastal Plain. Generally fewer sites occur farther inland and at higher elevations in the Piedmont, Ridge and Valley, and Southeastern Plains ecoregions. Indeed, the low ranges of the Appalachian Mountains appear to function as a partial barrier between the eastern and western portions of the species' range. The density of delineated sites is also relatively higher along the Eastern Great Lakes Lowlands and Erie Drift Plains.

Along the northern margin of the Spotted Turtle's range, populations occur from Waldo County, Maine and the Lakes Region of Carroll and Grafton Counties, New Hampshire, and in scattered Vermont localities and the Finger Lakes region of New York. At the extreme southern margin, populations are well-documented in Polk County, Florida, but confirmed sites are isolated in this region. In addition, isolated Spotted Turtle populations occur on many continental islands from Knox County, Maine, to morainal islands of Massachusetts and south at least to the barrier islands of the Outer Banks of Carteret County, North Carolina. The species is rare or presumed absent from the outermost barrier islands of southern North Carolina, South Carolina, Georgia, and Florida, though scattered populations are known from some interior (bayside) islands and other areas are under-sampled.

Species Distribution Model

We modeled the potential distribution of Spotted Turtles based upon a screened subset of 2,590 occurrence records, using an ensemble species distribution modeling approach, which incorporates generalized linear models, multiple adaptive regression splines, random forests, and boosted regression trees. We included 43 topographic, climate, soil, wetland, and landcover variables at multiple spatial scales (pixel, 90 m, 180 m, 360 m, 720 m, 1,440 m) for consideration as competing variables in model selection. Final ensemble models were used to generate surfaces depicting the relative probability of occurrence throughout the region. These models are intended to aid in the identification of locations for population sampling, as well as the development of the regional Conservation Area Network and site prioritization, and for spatially explicit analyses of environmental change.

Standardized Regional Population Assessment

Partners from Maine to Florida conducted standardized visual-encounter and trap-based sampling throughout the region. The protocol was field-tested in New England in 2014 based on a regional protocol for Blanding's Turtles, and was designed to be flexible, to fit within existing research programs, and to accommodate regional differences in seasonal activity periods, habitat structure, and research priorities. Observers placed up to four 200 m radius "reference plots" centered on potential Spotted Turtle habitat with plot centroids up to 800 m apart and conducted one of three sampling designs:

- Trap-based Rapid Assessment (TRA): placing five collapsible mesh minnow traps ≥30 m apart in each reference plot for four nights.
- Demographic Assessment (DA; trap-based): using the same approach but sampling for 12 nights instead of four.
- Visual Rapid Assessment (VRA): an observer visits a site three times during the survey season and actively searches for turtles on foot.

At sites with relatively low density of Spotted Turtles, researchers could conduct "high density" trapping within one or more reference plots by placing 10 traps instead of five. Data collected through the regional effort were compiled and maintained in a centralized database by the American Turtle Observatory (www.americanturtles.org) for pooled analysis.

From 2018 to 2021, 17 states and the District of Columbia sampled 309 unique sites for Spotted Turtles. Eighty-nine sites were surveyed using VRAs and 285 were trapped, with some overlap between the methodologies. A total of 7,536 traps were deployed in the field, for a total of 31,965 trap checks. In total, 3,399 unique Spotted Turtles were captured 4,698 times during the sampling period. The majority (84%) of captures were made by trap. Catch per unit of effort (CPUE, captures/functioning trap checks) for the region was 0.12. However, CPUE varied from 0.06 in the Southeast (NC, SC, GA, FL) to 0.16 in the Southern Mid-Atlantic (DE, DC, MD, WV, VA). In New England (ME, NH, VT, MA, RI) the CPUE was 0.14 and in the Northern Mid-Atlantic (NY, PA, NJ) the CPUE was 0.08.

We utilized the results of the standardized trap data to evaluate the relationship between landscape characteristics and relative abundance of Spotted Turtles. We calculated land cover, wetland, and landscape structure variables at multiple spatial scales surrounding each site, since broadscale landscape pattern has been shown to correlate with the abundance of other, related turtle species. We related Spotted Turtle abundance to environmental covariates using hierarchical closed-population N-mixture models. To account for a lack of independence among reference plots within close proximity, we included "macrosite" as a random effect, which we defined as all reference plots separated by ≤2 km.

Spotted Turtle abundance displayed strong positive associations with the diversity of wetland types (as designated by the National Wetlands Inventory, NWI) at the fine (30 m) scale and wetland ephemerality at the broad (7,680 m) scale and showed a strong unimodal relationship with wetland-regime (hydroperiod) diversity (480 m). Abundance was also strongly negatively associated with road density at the 480 m scale and weakly negatively associated with cultivated crop cover and imperviousness. Spotted Turtle probability of detection displayed a strong positive association with water temperature and strong negative associations with accumulated growing degrees days, trap-check visit, and day of year.

At 58 sites where >10 turtles were detected through standardized sampling we related the proportion of captures comprising juvenile turtles to environmental covariates using generalized linear mixed models with a binomial error distribution. Across these sites, 78 juveniles were captured, with the proportion of turtles that were juveniles ranging 0–0.37. The proportion of captures that were juvenile displayed a strong positive relationship shallow palustrine wetland diversity and cultivated crops and strong negative relationships with road density and the total amount of emergent wetland.

To complement the broad-scale population assessment, we used capture-mark-recapture loglinear models to estimate site-specific population abundances for sites where five or more turtles were captured and there were at least to recaptures. Abundance estimates were calculated for each of the 80 sites meeting the inclusion criteria using the function closedp.bc in the Rcapture package. Abundance estimates for the 80 sites (each made up of four, 200 m plots) ranged from 6.8 (SE=1.2) at a site in Delaware to 414 (SE=141) at a site in North Carolina, with a median of 48.5. Nineteen (23.8%) sites were estimated to support more than 100 turtles.

Status and Threats

Regional compilation of Spotted Turtle records from throughout the species' range as a part of this effort, combined with standardized sampling from Maine to Florida, confirms that the species remains extant in a variety of wetland habitats. It is also clear that Spotted Turtles occur locally in relatively high density in some areas, but that population sizes are generally small (within the temporal scale of the sampling reported here). The combined assessments presented in this plan are suggestive of extensive population decline since European colonization based on widespread wetland loss, intense development and impervious surface cover within the known range, and documented population decline at sites throughout the range due to anthropogenic wetland loss, habitat fragmentation, overcollection, and associated sources of habitat degradation and mortality. This evidence is consistent with the IUCN estimate that the species may have declined by 50%. Continued pressure from habitat loss and fragmentation, collection, and climate change, among other threats, will likely contribute to continued population decline in many areas.

We evaluated the threats influencing the persistence of representative Spotted Turtle populations and the species' overall evolutionary capacity through a series of analyses and expert polls. We elicited opinions from experts actively studying the species via two surveys to evaluate the most influential threats, and we evaluated the potential effects of wetland loss, land-use conversion, and climate change on Spotted Turtle distribution and demographics by conducting a literature review and complementary modeling approaches. We compiled information available on other identified threats, including illegal trade, disease and pathogens, subsidized depredation by mesopredators, invasive plant species, and hydrologic change. We also summarized modeled population trajectories from the literature, the relative protected status of populations, and management actions underway. Among the highest-perceived threats are: development (including road mortality), wetland loss, climate change, and collection.

Development.—Standardized sampling revealed that current Spotted Turtle abundance is negatively associated with road density at 480 m. Abundance was also negatively associated with cultivated crops at fine scales (60 m) and hay and impervious surface cover at 480 m, but these relationships were not significant. Greater proportions of juveniles were associated with greater amounts of cultivated crops, but lower road density.

We used GIS layers to estimate the amount of known Spotted Turtle habitat that has been influenced by or lost to development. The Spotted Turtle occurrence records we gathered for site delineation were composed of both current and historical records. To explore patterns between land cover and Spotted Turtle presence in the eastern United States, we compared mean values for land cover characteristics at Spotted Turtle sites with recent observations (current) and at sites where the species has not been seen in recent years (historical), assuming that historical sites, where no turtles have been documented in 30 years, might more often represent either low-density or functionally extirpated populations. Sites with more recent Spotted Turtle records have less urbanization (15.6% vs 19.6% impervious surface), and greater forest in the surrounding landscape, than sites where Spotted Turtles were documented historically but not recently. In fact, historical sites have almost as much impervious surface cover as they do total wetland area (19.9%). Across all sites an average of 16.2% of delineated habitat is impervious surface cover, representing direct habitat loss due to development, which is further compounded by fragmentation, road mortality, increased collection pressure, decreased water quality in wetlands, increased subsidized predators, and other factors.

Wetland Loss.—It has been estimated that overall, the United States lost 53% of its wetlands between the 1780s and 1980s (Dahl 1990). Although wetland loss has slowed as a result of federal and state regulation, the overall quantity and quality of freshwater wetlands in the United States has continued to decline in recent years. By another estimate, at least 179,500 acres of vegetated palustrine wetlands were lost between the 1950s and mid-2000s in 12 states, again indicating that the extent of habitat loss for this species has been large.

Climate Change.—We used occurrence records coupled with climate data in an ensemble modeling approach to model future changes in the climate suitability for the species. The model predicted substantial losses (>50%) of currently suitable habitat under future climate scenarios. The midwestern portion of the species range will remain more stable, proportionally retaining more currently suitable habitat compared to the eastern portion of the range.

To complement the modeling, we also calculated the projected change in the climate at the 2,351 known Spotted Turtle sites. Under moderate warming scenarios, minimum January temperatures are projected to increase up to 2.5˚C for some Spotted Turtle sites, while most extreme scenarios project an increase in minimum January temperatures of 4–4.5˚C by the year 2050. Under moderate warming scenarios, maximum July temperatures are projected to increase from 2.5–3˚ C for some Spotted Turtle sites while extreme scenarios project a 5.5–6˚ C increase in maximum July temperatures by 2050. Under low emission scenarios, precipitation is projected to increase an annual average of 15 cm at Spotted Turtle sites in southern states, while decreasing slightly in northeastern region (-5–0 cm).

In addition to changing temperature and precipitation patterns, sea levels are projected to rise as a result of anthropogenic climate change, which will substantially affect Spotted Turtle populations in coastal areas. To examine the impacts of different sea level rise (SLR) scenarios on coastal Spotted Turtle sites, we used the National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management's Sea Level Rise Wetland Impacts and Migration raster data to estimate the number of delineated Spotted Turtle sites that might be affected under various SLR scenarios. Almost half of the 2,351 delineated Spotted Turtle sites in the eastern United States are within coastal areas (n=1,064). Using observation-based extrapolation, it is probable that by the year 2050 sea level along the East Coast of the United States will have risen by one foot, impacting 36% (n=379) of coastal Spotted Turtle sites, and 6% of the Spotted Turtle habitat within mapped sites could be lost. Projected habitat loss could reach 11% by 2100 with an additional foot of SLR. Spotted Turtle sites in southeastern states are particularly vulnerable to SLR and could lose up to 10% of habitat by 2050 and 20% by 2100. However, direct seawater overwash and wetland loss associated with storm-caused erosion were observed in New England Spotted Turtle sites during this study, emphasizing that the effects of SLR are widespread in the region, though complex and unpredictable.

Illegal Collection.—The degree to which collection is affecting North American Spotted Turtle populations is still largely unknown, however in recent years it has become clear that the impact could be substantial. We compiled available information to try to assess the magnitude of the threat to Spotted Turtle populations and describe ongoing efforts to minimize it. The species has been regularly available in commercial markets for at least 50 years (Connecticut Valley Biological Supply 1962; 1964), initially as a biological supply animal and eventually as a pet species. Early price data for the Spotted Turtle suggests that the species was relatively easy to obtain in the wild, but later, the average real price per adult (adjusted for inflation) from 1998–2021 was 24.25 times the real price in

1962–1965, suggesting a regional decline in availability (or ease of collection) between 1965–1998, likely exacerbated by increased demand.

In 2000 and 2013, the United States proposed that the Spotted Turtle be added to Appendix II of the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES), recording 196 declared imports of Spotted Turtle individuals to the United States and 1,203 exports from 1995 to 1999, and 727 export shipments of 7,881 Spotted Turtles from the United States from 1999 to 2010. The proposal was accepted in 2013, and the Spotted Turtle was added to Appendix II of CITES in 2013. Since CITES listing, the CITES trade database contains 99 cases of legal Spotted Turtle imports and exports from 2013-2020. Of these cases, trade of live Spotted Turtles was reported in 98 cases with 1,393 Spotted Turtles reported by importers and 2,006 reported by exporters. The United States exported 44% of these turtles and Hong Kong imported nearly 92% of all traded turtles. Illegal collection has also been a major concern in recent years. There have been at least 11 major United States cases involving the confiscation of 11,892 freshwater turtles from May 2018 through December 2020; Spotted Turtles were found among the confiscated turtles in four of these cases.

From a review of the available information, the trade and trafficking of wild Spotted Turtles is occurring across a broad-scale and in large enough numbers to potentially influence population viability. Given the potential for collection to influence Spotted Turtle populations, additional information is necessary to further quantify the scale of the threat and to identify areas and sites that are most vulnerable.

Other Threats.—Other threats to Spotted Turtle populations include emerging pathogens, depredation, and localized hydrologic changes. These warrant additional research or surveillance throughout the region. When coupled with the other threats mentioned above, these threats may have synergistic, significant, and/or variable detrimental effects on population viability.

Conservation Area Network

Despite these myriad threats facing Spotted Turtle populations and clear habitat and population loss over the last centuries, it is evident that relatively large and connected Spotted Turtle populations are still well distributed across the landscape, though they may be absent from heavily fragmented areas. At least 19 sites sampled in this effort are estimated to contain over 100 turtles, and approximately 28% of mapped Spotted Turtle habitat in the eastern United States has some level of protection (GAP status 1, 2, or 3). However, only 15.1% of the 2,351 delineated sites are more than 50% protected using this designation (though the level and proportion protected varies throughout the region).

The present situation provides ideal opportunities to conserve a vulnerable, declining species at landscape scales while there is still time for relatively inexpensive conservation measures such as land protection in key areas through broad-scale, collaborative conservation efforts. To prioritize sites for conservation, partners developed a Conservation Area Network (CAN) to identify populations and landscapes that represent priorities for Spotted Turtle conservation. This CAN focuses specifically on priorities for land protection, habitat management, and future sampling in data-deficient, but highly suitable landscapes.

The Spotted Turtle CAN development process was based on those used for the Blanding's Turtle (Willey and Jones 2014) and the Wood Turtle (Jones et al. 2018). The process included characterizing and ranking the 2,351 delineated Spotted Turtle sites by calculating 18 characteristics in four classes for each site, weighting each characteristic based on importance via an expert poll, and then selecting the highest-ranking sites in each state, ecoregion, and watershed in three tiers.

Areas identified as **Focal Core Areas** represent the highest regional priorities in protecting the evolutionary potential of the species in the eastern United States; **Sampling Opportunities** are those with high habitat quality according to GIS metrics, but where there are limited numbers of records or previous sampling; **Management Opportunities** were selected to represent areas where Spotted Turtles could be elevated to a management priority given current land use and management and they fell into three main categories: Agricultural Mitigation Sites, Protected Sites, and Supporting Sites.

The resulting spatial data layer is intended to be used by biologists, managers, and conservationists to provide regional context, support land protection and mitigation efforts, and provide a basis for developing finer-scale conservation plans. It can also be used as a baseline to assess changes in landscape conditions (i.e., availability of wetland habitat and landscape composition and fragmentation) within priority Spotted Turtle sites.

Of the 2,351 Spotted Turtle sites delineated, attributed, and scored in the eastern United States, 15% were selected for the CAN, representing 39% of all delineated habitat. Focal Core Areas made up 8% of all sites and 50% of selected sites, Sampling Opportunities accounted for 4% of all sites and 28% of selected sites, and Management Opportunities represented 3% of all sites and 23% of selected sites. While this CAN was based on 11,975 Spotted Turtle records and four years of sampling data across 17 states and District of Columbia, the full distributional extent of the species is still partially unknown. Therefore, this CAN is designed to be updated systematically as more information is acquired within data-deficient areas such as the southern portion of the range.

Conservation Action Plan

The overarching goal of this regional Conservation Plan is conserving **self-sustaining populations of Spotted Turtles throughout their current occupied range in the eastern United States.** To achieve this, partners developed a Conservation Action Plan aimed to: 1) prevent population declines at high priority sites throughout the eastern United States that are representative of the varied locations and habitats in which Spotted Turtles occur in order to maintain their capacities to evolve in the face of environmental change, 2) encourage management at sites identified as "Management Opportunity Sites", and 3) address data gaps including additional sampling at those sites designated as "Sampling Opportunity Sites". Specific objectives and actions identified are:

Objective 1. Achieve no net loss of suitable habitat within "Focal Core Areas" identified in the Conservation Area Network (CAN) by:

a) maintaining the habitat quality of high priority sites across the region
b) minimizing fragmentation and development within Focal Core Areas
c) increasing protected land status through strategic acquisitions that protect functional habitat components

Objective 2. Reduce other major threats.
Habitat loss and related effects (including road mortality) and illegal collection are identified as major threats to Spotted Turtle populations in this Plan. To address habitat loss, partners emphasize the need for land conservation at Focal Core Area sites as part of Objective 1. To complement those efforts and mitigate additional threats, partners identified the following necessary actions:

a) Minimize illegal collection
b) Increase road mortality mitigation measures
c) Implement habitat management actions at CAN sites, with an emphasis on Focal Core Areas and Management Opportunities
d) Evaluate and monitor the effects of climate change (including sea level rise) on representative and priority populations

Objective 3. Maintain adaptive capacity of representative and high-priority Spotted Turtle populations under changing environmental conditions by ensuring that robust and representative populations are conserved across political boundaries, ecoregions, ecosystems, and genetic groups.

Objective 4. Address data gaps, including evaluating effectiveness of management actions and continued sampling across the species range, with a focus on "Sampling Opportunities" identified in the CAN.

Objective 5. Continue collaboration and coordination including: hold regular working group calls during periods of active coordination, undertake a symposium (currently planned to be held in Pennsylvania in July 2023), establish partnerships and collaborations with the Midwest Region and Canadian Provinces, periodically (7–10 yr) resample sites to assess change, and update the Conservation Area Network and Conservation Plan as more information becomes available.

Part I. Ecology of the Spotted Turtle

Chapter 1. Ecology of the Spotted Turtle

John C. Garrison, Cullen M. Mackenzie, Michael T. Jones, Lisabeth L. Willey, Jessica Meck, Molly Parren, Houston C. Chandler, Donald J. Brown, Savannah M. Kerns, H. Patrick Roberts, Phillip deMaynadier, Lori Erb, Scott Buchanan, Eric B. Liebgold

Summary

Here we summarize the biology, ecology, natural history, history, threats, legal status, and management of the Spotted Turtle (*Clemmys guttata*, Schneider 1792). The Spotted Turtle is a freshwater emydine (Emydidae, subfamily Emydinae) turtle widespread in eastern North America. The Spotted Turtle has declined substantially due to anthropogenic wetland loss, habitat fragmentation, overcollection, and associated sources of habitat degradation and mortality. Spotted Turtles are of widespread conservation concern: they are listed as Endangered globally by the IUCN, Endangered in Canada, considered either Special Concern or Threatened in five states, Endangered in three states, have no listing status in 13 states, and are labeled as a Regional Species of Greatest Conservation Need (RSGCN). Though widely distributed from southern Ontario to central Florida, Spotted Turtles occur in two distinct geographic regions: (1) the eastern seaboard from Maine to Florida; (2) the southern and eastern Great Lakes region from Indiana to southern Ontario. Spotted Turtle habitat generally encompasses a wide variety of shallow seasonal or heavily vegetated wetland habitats. Although primarily aquatic for most of the year, Spotted Turtles make extensive upland movements into terrestrial habitat to move between wetlands, aestivate, and nest. Active periods vary annually and regionally, but Spotted Turtles usually emerge in spring, mate throughout the spring, nest in late spring and early summer, aestivate in summer, and begin to overwinter in mid fall. Females produce one to three clutches containing an average of one to six eggs per year. Hatchlings usually emerge in late summer and are thought to be subjected to high depredation rates by mesopredators. Threats to Spotted Turtle populations include road mortality, habitat loss and degradation, climate change, disease, collection for the pet trade, and invasive plants. Further research on lifetime patterns of movement and dispersal, as well as density-dependent mechanisms associated with reproduction, site fidelity, and population genetics are necessary to adequately conserve self-sustaining populations of this species at landscape scales.

Habitat

Ecological Space

Spotted Turtle populations occur in a variety of wetland habitats, but are usually associated with shallow, seasonal and/or vegetated wetlands including emergent freshwater marshes, scrub-shrub swamps, *Sphagnum*-dominated bogs, fens, low-flow streams, beaver ponds, vernal pools, forested swamps, and occasionally estuarine marshes (Babcock 1919; Beaudry et al. 2009; Rasmussen and

Litzgus 2010*b*; O'Bryan et al. 2016; Buchanan et al. 2017; Oxenrider et al. 2018; Howell et al. 2019; Oxenrider et. al 2019; Chandler et al. 2020). They typically avoid deep and oligotrophic bodies of water such as lakes and reservoirs (Mitchell 1994; Kleopfer et al. 2014; Buchanan et al. 2019*a*). Spotted Turtle populations are also known to occur, sometimes in high densities, in ditches associated with anthropogenic activities including managed pine plantations, drainage and agricultural ditches, as well as cranberry operations in New England (O'Bryan 2014; O'Bryan et al. 2016).

Physical Characteristics of Wetland Habitats

Spotted Turtles occur primarily in freshwater systems (Ernst and Lovich 2009; DeCatanzaro and Chow-Fraser 2010; COSEWIC 2014). Many of the wetlands where Spotted Turtles are found have substrates consisting of thick organic layers (Ernst et al. 1994; Ernst and Lovich 2009; Rasmussen et al. 2010*a*) with variable canopy cover, from open, partially open, to closed canopy (Rasmussen 2009; Howell et al. 2016), depending on context and location within the range. Robust populations are often associated with wetland systems that support vegetation characterized by high structural diversity. In Georgia, Spotted Turtles are found in blackwater creek swamps, river swamps, temporary depression wetlands, and ditches (Stevenson et al. 2015). Refsnider et al. (2022), studied a population of Spotted Turtles in seasonally wet prairies, swamp forests, and fens. In Maryland, Spotted Turtles occupy vernal pools complexes, flooded forests adjacent to marshes, wet fields, and puddles (Ward et al. 1976). In Maine, Spotted Turtles are found more often in wetlands with greater emergent cover, wetland size, hydroperiod, sun exposure, and proximity to hibernation sites (Joyal et al. 2001; Beaudry et al. 2009). In Ontario, Yagi and Litzgus (2012) studied a population of Spotted Turtles in a partially mined peatland that became flooded by Beaver (*Castor canadensis*).

While primarily found in freshwater systems, Spotted Turtles are occasionally found in brackish environments (Agha et al. 2018). Observations of Spotted Turtles occurring or residing in brackish marshes have been reported from Georgia, North Carolina, Maryland, Delaware, and Massachusetts (Neil 1958; Schwartz 1961; Garrison et al. 2021; O'Dell et al. 2021). Although Spotted Turtles may be able to tolerate seasonal or occasional seawater influence, it is unknown whether use of brackish environments is a facultative response to a loss of preferred freshwater habitat.

Physical Characteristics of Upland Habitats

Spotted Turtles utilize different terrestrial ecotypes throughout their broad latitudinal distribution. Although primarily aquatic for most of the year, Spotted Turtles can undertake extensive upland movements to nest (Carroll 1991; Milam and Melvin 2001; Beaudry et al. 2010*a*). During their active season, Spotted Turtles may spend substantial time in upland environments (Ward et al. 1976; Graham 1995; Milam and Melvin 2001). Individuals in some populations will aestivate during the summer to conserve energy (Ernst 1982; Haxton and Berrill 2001; Litzgus and Brooks 2000; Milam and Melvin 2001). Spotted Turtles use a variety of upland habitats including mixed forests, clearings, rights-of-way, lawns, agricultural fields, road edges, and early successional habitat for nesting, aestivation and traveling between wetlands (Ernst and Lovich 2009). Climate change could influence

Spotted Turtles upland usage both temporally and spatially (Milam and Melvin 2001). In South Carolina, Litzgus and Mousseau (2004*a*), studied a population that was located in a seasonally flooded hardwood bottomland swamp. In Maine, Spotted Turtle upland habitat is described as low-elevation, uneven terrain with shallow soils, rocky outcrops, dominated by mostly mixed forest, though often near lower-density residential development (Beaudry et al. 2010*a*). Haxton and Berrill (1999), studied a population of Spotted Turtles in Ontario and described the uplands as gently rolling terrain with exposed igneous and metamorphic rock or covered by a thin layer of drift, with swampy deposits of organic soils.

Nesting Habitat

Spotted Turtle nesting sites are highly variable and may locally encompass well-drained clearings in upland habitats or hummocky vegetation within wetlands. Nesting occurs in both open and closed canopy conditions, though northern populations generally nest in open-canopy sites. In Georgia, nests were typically laid on the periphery of wetlands and were dug in a variety of substrates, including loose soil and leaf litter, sphagnum moss clumps, rotting logs, and raised hummocks containing thick grass clumps (Chandler et al. 2022). In South Carolina, nests were laid in decaying coarse woody debris, and small piles of soil covered with dead vegetation (Litzgus and Mousseau 2006). In Ohio, nesting took place in flooded grasslands, fens, swamps, and forested habitats (Refsnider et al. 2022), and eggs were laid in sphagnum, grasses, rotten logs, and soil. Spotted Turtles in Massachusetts nested in disturbed portions of a sandy hayfield (Milam 1997; Milam and Melvin 2001), and Jones (unpubl. data) observed nests on road shoulders, powerlines, gravel pits, and an elevated causeway to a water pumping station. In Maine, females nested in a variety of anthropogenic and natural settings, the latter consisted of several nests in sphagnum mats and hummocks within wetlands, and one upland rocky outcrop (Beaudry et al. 2010*a*). In Ontario, females were observed nesting in pockets of soil, lichen, and vegetation atop rocky outcrops (Litzgus and Brooks 1998*a*). Over large areas of their range, Spotted Turtles will nest in anthropogenically-created habitats such as lawns, gardens, roadsides, causeways, pastures, clearings, and rights-of-way (Ernst 1970*a*; Litzgus and Mousseau 2006; Beaudry et al. 2010*a*). Eggs are typically deposited into loose soils, dead vegetation, lichen, sphagnum moss, decaying coarse wood debris, and hummocks (Ernst and Lovich 2009). Nesting may also take place in brackish wetlands with considerable levels of salinity (Garrison et al. 2021). The high variability of nesting habitat utilized by Spotted Turtles might indicate a latitudinal variation to nesting, or a facultative response to site specific habitat characteristics, though more field studies are needed to confirm this.

Canopy Floristic Associations

Hardwood tree species commonly found in forested swamps inhabited by Spotted Turtles include Red Maple (*Acer rubrum*), Sweet Gum (*Liquidambar styraciflua*), Black Tupelo (*Nyssa sylvatica*), as well as other species. Conifer species associated with Spotted Turtle wetlands include Atlantic White Cedar (*Chamaecyparis thyoides*), Baldcypress and Pondcypress (*Taxodium* spp.), and several pine species (*Pinus echinata; P. serotina*; *P. strobus; P. taeda*). Spotted Turtle aggregations occur frequently in association with Atlantic White Cedar swamps, and some Spotted Turtle populations occur within Longleaf

Pine (*Pinus palustris*) savannas from Virginia to Florida. Spotted Turtles in the Mid-Atlantic regions and southward are known to occur in Loblolly Pine plantation forests (O'Bryan 2014; O'Bryan et al. 2016). Near the extreme northernmost range margin in New England, Spotted Turtles may be found in association with northern conifers such as Black Spruces (*Picea mariana*), Balsam Fir (*Abies balsamea*), and Tamarack (*Larix laricina*). Hardwood tree species in the upland matrix include various oaks (*Quercus* spp.), hickories (*Carya* spp.), birches (*Betula* spp.), cherries (*Prunus* spp.), and maples (*Acer* spp.). Conifer species in the upland matrix include various pines (especially *Pinus strobus* and *P. rigida*), and Eastern Hemlock (*Tsuga canadensis*; Milam and Melvin 2001; Litzgus and Mousseau 2004*b*; Reeves and Litzgus 2008; Howell et al. 2019; Oxenrider et al. 2019).

Subcanopy Floristic Associations

Herbaceous vegetation varies between sites and among regions, but many ferns, grasses, and shrubs are common in adjacent upland forests. Common grasses and emergent vegetation found in Spotted Turtle habitat include: Soft Rush (*Juncus effusus*) and other rush species, Common Steeplebush (*Spiraea tomentosa*), Common Greenbrier (*Smilax rotundifolia*), Jewelweed (*Impatiens capensis*), Asters (*Aster* spp.), Goldenrods (*Solidago* spp.), Cattails (*Typha* spp.), Cinnamon (*Osmunda cinnamomea*), Royal (*Osmunda regalis*), Sweet (*Comptonia peregrina*), and Marsh Fern (*Thelypteris palustris*), Tussock Sedge (*Carex stricta*), and other sedges (Kaye et al. 2001; Ward et al. 1976; Milam and Melvin 2001). Additionally, invasive plant species such as the Common Reed (*Phragmites australis*), Purple Loosestrife (*Lythrum salicaria*), Multiflora Rose (*Rosa multiflora*), Common (*Rhamnus cathartica*), and Glossy Buckthorn (*Rhamnus frangula*) are present in Spotted Turtle habitats (Lewis et al. 2004; Rasmussen and Litzgus 2010*b*; Yagi and Litzgus 2013; Chandler et al. 2020). Ground cover may consist of mosses, lichens, dead vegetation, gravel, and sand (Wilson 1994; Schmidt 2003; Kaye et al. 2001; Reeves and Litzgus 2008). Buttonbush (*Cephalanthus occidentalis*), Highbush Blueberry (*Vaccinium corymbosum*), Common Winterberry (*Ilex verticillata*), Sheep Laurel (*Kalmia angustifolia*), Red Maple (*Acer rubrum*), Coastal Sweetpepperbush (*Clethra alnifolia*), Northern Bayberry (*Myrica pensylvanica*), and Spicebush (*Lindera benzoin*) are common shrubs found in Spotted Turtle wetlands and adjacent understory habitats (Joyal et al. 2001; Kaye et al. 2001; Beaudry et al. 2009; Buchanan et al. 2017).

Activity

General Activity Patterns and Constraints

Spotted Turtles are poikilothermic, and their internal temperature varies considerably throughout the year (Ernst 1982; Rasmussen 2009). Warming water temperatures in hibernacula during early spring trigger Spotted Turtles to become active (Litzgus et al. 1999; Ernst and Lovich 2009; Ernst 1976; Lovich 1988). In southern regions of their range, Spotted Turtles emerge from winter quiescence in late February to early March, but have been observed to emerge as early as mid-January (Litzgus et al. 1999; Litzgus and Mousseau 2004*b*; O'Bryan 2014; Stevenson et al. 2015; O'Bryan et al. 2016). In northern regions, Spotted Turtles emerge between early April and early May, but are often active by mid-March in warm years with little ice cover. They begin basking and foraging shortly after water temperatures reach 7 to 14˚C (Milam and Melvin 2001; Litzgus and Mosseau 2004*b*; Beaudry et al. 2009; Ernst and Lovich 2009). Spotted Turtles are found aggregating during the courtship and mating period ranging from late March through June (Ernst 1976; Ernst and Zug 1994) but also have a fall courtship period in some southern populations (Litzgus and Mousseau 2006; Chandler et al. 2019). In the summer, when water temperature reaches 30˚C and seasonal pools dry out, turtles may aestivate terrestrially in leaf litter, soils, puddles, and under coarse woody debris (Ernst et al. 1982; Wilson 1994; Milam and Melvin 2001); in some areas they may continue to be active under heavy vegetation cover (Mitchell and Buhlmann 2007). Of the 41 Spotted Turtles tracked by Beaudry et al. (2009), 31 were observed in some form of active season aestivation, generally in leaf litter and sphagnum beds beneath a forest canopy. However, it is not clear in some areas whether Spotted Turtles are truly aestivating (Litzgus and Mousseau 2004*b*), and in some southern populations the species appears to be active year-round (Chandler et al. 2019). Activity may increase again as temperatures cool or when seasonal pools refill but will start to reduce as temperatures decrease in autumn (Haxton and Berrill 1999; Litzgus and Brooks 2000). Spotted Turtles will move to their overwintering wetlands as water and air temperatures become cool in October through November (Joyal et al. 2001; O'Dell et al. 2021). Spotted Turtles exhibit high fidelity to overwintering sites which may be shared communally and typically occur within vernal pools, wetlands, root systems, hummocks, or rocky structures (Litzgus et al. 1999; Buchanan et al. 2017; Nagle et al. 2021). Although there are numerous field studies that have investigated the general activity patterns of Spotted Turtles in the wild, additional field studies are necessary to fully understand the seasonal movement ecology of this species across its range.

Home Range

There is wide variation in reported Spotted Turtle home range sizes, from 0.2–34.4 hectares (Milam and Melvin 2001; Chandler et al. 2019; see Table 2-2). Spotted Turtles are most active during their nesting season, when females will make long nesting movements, and males will travel long distances in search of females (Beaudry et al. 2009; Stevenson et al. 2015). Home ranges are typically similar between sexes, though males tend to have smaller home ranges than females (Ernst 1970*b*; Buchanan et al. 2017; Litzgus and Mousseau 2004*b*). Chandler et al. (2019), reporting on populations in Georgia, found Spotted Turtles travel on average 15 m/day in spring (peak mating season), compared to five m/day in late summer and fall. Spotted Turtle hatchling emergence ranges from late August to mid-October (Carrol and Ultsch 2007). Maximum distances traveled from hibernacula in Massachusetts averaged 265 m annually, and total distance traveled annually averaged 327 m in Ontario (Milam and Melvin 2001; Seburn 2012). In Rhode Island, Buchanan et al. (2017) observed an increase of the home range of Spotted Turtles after the creation of a nearby early successional habitat and emphasized the importance of protecting winter hibernaculum. See Table 2-2 for additional movement information reported in the literature.

Life History

Maturation and Longevity

Spotted Turtles reach sexual maturation between seven and 13 years in the wild; however, the age at which individuals may become sexually mature may be influenced by latitude and other environmental conditions (Ernst and Lovich 2009). For a population in Ontario, females and males matured at 12–15 years and 11–13 years, respectively (Litzgus and Brooks 1998*b*). Litzgus (2006) estimated maximum longevity of 65 years and 110 years for males and females, respectively, from 24 years of population monitoring in Ontario. In addition, growth rates in Spotted Turtles are slow (Seburn 2003). In an Illinois population, Edmonds et al. (2021) found that Spotted Turtles continue to grow post-maturation, though continuous annual plastron growth is minimal. Edmonds et al. (2021) used interval and age-specific growth models to infer that Spotted Turtles exhibit differing growth and maturation rates between sexes, with females maturing from 7–12 years and males maturing at 11–34 years. Individuals found in northern populations may be noticeably larger than turtles found in southern populations (Ernst and Lovich 2009; Litzgus et al. 2004).

Reproduction

The reproductive biology of Spotted Turtles varies in important ways throughout their geographic range (Litzgus and Mousseau 2006). Copulation may begin shortly after their active season, when water temperatures are conducive for activity, and typically takes place underwater (Ernst 1967; Ernst 1976). Mating may take place throughout the active season, although the majority of studies on Spotted Turtle reproduction observed mating from February to May (Ernst 1967; Litzgus and Mousseau 2006). Nesting can take place throughout May to July; during this period females may move over 450 m to reach suitable nesting habitat (Milam and Melvin 2001; Beaudry et al. 2010*a*; Joyal et al. 2001; Chandler et al. 2022). Gravid Spotted Turtles spend more time basking during the weeks preceding oviposition (Chandler et al. 2022). Nesting usually takes place after dark and may take females up to eight hours to complete (Litzgus and Brooks 1998*a*). Clutch size and number of clutches produced per year vary considerably throughout their range. Females that are in healthier body condition typically produce larger and heavier eggs, although this will not change the size of the clutch (Litzgus et al. 2008). In the southern portion of their range, Spotted Turtles may produce up to three clutches per year, with a clutch size ranging from one to four eggs (Litzgus and Mousseau 2003; Chandler et al. 2022), whereas populations in the north may produce one clutch, with a clutch size of three to five eggs (Litzgus and Mousseau 2003; Ernst and Zug 1994). Incubation ranges from 72 to 90 days, and hatchlings emerge from nests in late summer and throughout fall (Litzgus and Mousseau 2006).

Like many other species of freshwater turtle, the survival, ecology, and behavior of Spotted Turtle hatchlings and juveniles is not fully understood. In Ohio, 34 hatchlings were radio-tracked from their nests to overwintering habitat; one was depredated, five were likely depredated, 19 overwintered successfully, while nine were suspected to overwinter unsuccessfully (Refsnider et al. 2022). Additionally, Refsnider et al. (2022), found that macro-habitat surrounding the nests did not affect hatchling survival, while micro-habitat did. In Maine, among six nests that were monitored, only two (33%) successfully hatched (Beaudry et al. 2010*a*), with at least one nest depredated by ants. Hatchlings were observed emerging from a single nest in Massachusetts on September 13, and a single individual was radio tracked for 15 days until it was depredated by a Northern Green Frog (*Lithobates clamitans*; DeGraff and Nein 2010). Furthermore, 12 Spotted Turtle hatchlings were observed to have hatched from August 20 to October 19 in New Hampshire (Carroll and Ultsch 2007). Additional field studies are needed to investigate these crucial periods in their life history when the mortality rate is likely high.

Populations and Demography

Demography and Population Size

Historical population data on Spotted Turtles are scarce. Storer (1839) noted that species was the "most common" species of freshwater turtle in Massachusetts. Thoreau (2009) noted Spotted Turtles with great regularity in Middlesex County, Massachusetts in his journals, particularly those from the 1850s.

Spotted Turtle populations have been documented to be relatively small and/or isolated in parts of the range and robust and contiguous with other areas of occurrence in other locations. A Massachusetts population of Spotted Turtles had 18.8 individuals per hectare and homogenous sex ratios (Kaye et al. 2001). A demographic study conducted of an isolated population on an island documented skewed sex ratios, differences in body size between males and females, and 21.4 individuals per ha in a single wetland (Reeves and Litzgus 2008). Seburn (2003) studied a population in Ontario with 32 observed individuals and estimated population size to be 45 individuals, estimated adult average age to be 28.9 years, and documented a female skewed sex ratio of 3.5:1. A long-term demographic study of two populations towards the western extent of its range in Illinois, found that survival increased with age, and sex ratios were mostly equal over 28 years (Feng et al. 2019*a*).

Documented declines of Spotted Turtle populations have been recorded throughout their range and models have been used to project changes in populations going forward. A study in Maryland that used population modeling projected a 49% decline in population size within 30 years and probable extinction within 150 years (Howell et al. 2019; Howell and Seigel 2019). A stochastic model for a remote and isolated population in Ontario predicted a 60% chance of extirpation in 100 years (Enneson and Litzgus 2009). Despite many studies researching the population demography of Spotted Turtles, additional field studies will help discern the true demographics and viability of representative populations.

Population Trends

There is limited quantitative information available documenting Spotted Turtle population trends and few long-term demographic studies that specifically evaluate population viability. The majority of long-term studies indicate population decline or severe risk of decline, on both protected and unprotected properties. There is marked variation in the information available across the Spotted Turtle's range. The extreme southern range-extent has the most limited population-level information, although locations in North Carolina and adjacent states may harbor some of the most robust populations (see Chapters 5 and 7). In this Chapter, we summarize the information available about population trends throughout the species' range.

Canada.—Browne and Hecnar (2007) reported that the Spotted Turtle became extirpated from Point Pelee National Park, Ontario between the 1970s and early 2000s. They attributed the cause to heavy depredation of turtle nests by raccoons, road mortality, habitat succession, and possible chemical contamination. The park also sustained massive loss of forested swamps and shallow wetland as a result of draining for farmland in the early 20th century, which likely caused a contraction of the local Spotted Turtle population. One of the longest mark-recapture studies conducted found that a Georgian Bay island population was healthy and stable across a 24-year period (1977 to 2000; Litzgus 2006). The estimated instantaneous immigration/recruitment rate (0.265) was more than twice the estimated instantaneous mortality/emigration rate (0.106), suggesting the population was stable or increasing. However, Litzgus (2006) noted that the high survivorship rates made this population highly sensitive to fluctuations in adult mortality. Seburn (2003) reported evidence of a 20% decline in another Ontario Spotted Turtle population between 1983 and 2011 (58 to 45 individuals), but the results were not statistically significant between time periods.

Northeastern United States.—A population viability analysis (PVA) was conducted for six Maine populations at risk of road mortality and found that every population sampled had at least a 30% probability (range 30%–98%) of experiencing a 50% decline in population size within 100 years (Beaudry et al. 2008).

In Massachusetts, over a two-year study Kaye et al. (2001) collected data indicating a healthy population with an equal sex ratio and successful recruitment with 23 juveniles observed. All age classes were captured (hatchlings to adults). Their population density was also estimated to be higher than that reported by Graham (1995) in a central Massachusetts population, but lower than those estimated in Pennsylvania by Ernst et al. (1994).

Three populations in Massachusetts that were assessed as part of the regional C-SWG sampling effort reported in this document (see Part III) had been previously studied by Graham (1995) and Milam and Melvin (2001; Willey, Roberts, Jones, and Milam, unpublished data). Two of these sites are conserved as water supply areas, two are primarily forested, and one has substantial agricultural cover. Little land-use change had occurred at any of the sites in the intervening time, although water levels had fluctuated due to beaver activity and invasive plant species had invaded a nesting area at one site. Estimates for these sites from 1989–1995 were 98, 18, and 43 turtles, and those from 2018–2019 were 100, 25, and 31.5, respectively. These findings suggest relative population stability at two sites over several decades, and a potential decline of 25–40% at the third site; though it is possible that the population center shifted due to habitat change. Results emphasize the variation in population parameters across space and time and indicate that even relatively stringent land protection efforts (such as those for watershed protection) may be inadequate to ensure long-term persistence of Spotted Turtle populations which are vulnerable to a suite of variable external threats and may require larger areas of protection to account for wetland succession and habitat change.

Midwest.—Multiple studies have recorded evidence of Spotted Turtle population declines in Ohio. Despite being historically abundant throughout the state, only 48 Spotted Turtle locations were recorded between 1958 and 2000 and of those locations, 17% (8 of 48 records) no longer contain wetlands, eliminating the potential for a population (Lewis et al. 2004). Lewis et al. (2004) identified three main clusters of potential populations remaining in the state, but they are isolated (5, 20, and 30 km apart) and wetlands are heavily fragmented and threatened by invasive plants and development. Hawkins and Lewis (2002) studied a southwestern Ohio population (1981 to 2001) and estimated that it declined from 75 Spotted Turtles in 1990 to 20 in 2001. Lovich (1989) also documented population decline at Cedar Bog Nature Preserve.

Illinois is the westernmost range extent for the Spotted Turtle and has only two remaining populations. The species was first documented in 1927 and populations have slowly been extirpated due to habitat loss and poaching (Johnson 1983). However, Feng et al. (2019*a*) documented that both remaining populations exhibited robust population structures and were demographically healthy across a 28 year-period (1988 to 2016). It was noted that given their small size, the populations remain susceptible to stochasticity, anthropogenic disturbances, and genetic degradation.

Mid-Atlantic.—Howell et al. (2019) documented a 50% decline in a Maryland population over the course of 30 years (1987 to 2017). The decline was attributed to lack of recruitment caused by an increased abundance of subsidized mesopredators. While the population is on protected land, it was noted that external factors such as road mortality, mesopredators, invasive species, habitat succession, and poaching offset the benefit of protection status. This population was also evaluated using a PVA to consider the effects of road mortality (Howell and Seigel 2019). The analysis estimated that an additional 2% population loss from road mortality would drastically decrease the population's growth and lead to predicted extinction. However, mortality rates were derived from only four mortality events and demographic parameters were based on population estimates. The authors also noted that the comparison of long-term mark-recapture data from the 1980s–90s and 2014–2017 demonstrated that while recruitment and multiple age classes were present during each time period, a quantitative demographic analysis showed that the populations were likely not viable and would be extirpated within the next 150 years.

In Virginia, Wilson (1999) documented a 37% decline in suitable habitat across a 35-year period at a known Spotted Turtle site. The change in habitat was attributed to increased siltation linked to urban development in the surrounding landscape, leading to succession and drier habitats on site.

While population trend data was not available, aggressive mitigation efforts were recommended to prevent population decline.

Mitchell and Buhlmann (2007) conducted a status assessment for Virginia Spotted Turtle populations and determined that populations across large areas of the state would likely become extirpated due to urban expansion. During their study period, six (of 28) populations inventoried were lost due to urbanization. They did note that other populations in the state were likely secure on protected lands or rural private lands.

Prior to 2019, Spotted Turtles had been documented in the eastern panhandle region of West Virginia in Berkeley County (one historic population), Hampshire County (one contemporary population), and Jefferson County (two contemporary populations, one the result of translocation; Knight 1985; Humphries 2002; Breisch 2006). Although Spotted Turtles have not been documented in the north-central and northern panhandle regions of the state, these regions are considered to be within the species' broad geographic distribution (Powell et al. 2016). From 2019–2021, 80 Spotted Turtle individuals were captured during trap-based surveys at 63 sites in the eastern panhandle, north-central, and northern panhandle regions of West Virginia (Mota 2022). Spotted Turtles were encountered in the eastern panhandle in Hampshire County, Jefferson County, and Hardy County, but were not detected in Berkeley, Grant, and Morgan Counties. Spotted Turtles were not encountered in the north-central (Preston County) or northern panhandle (Brooke and Hancock Counties) of West Virginia (Mota 2022).

Previous surveys of the natural population in Jefferson County identified 103 unique individuals captured across 19 visual encounter surveys (Humphries 2002). From 2019–2021, 28 Spotted Turtle individuals were captured at this site over 180 trap nights (Mota 2022). No turtles were captured at the other Jefferson County site where six Spotted Turtles had been translocated in 1985 (Knight 1985; Mota 2022). Previous surveys of the Hampshire County population resulted in 21 unique individuals documented across 690 trap days and opportunistic visual encounters (Breisch 2006). During the recent survey effort at this site, 11 individuals were encountered across 180 trap days (Mota 2022). These results indicate that the natural Jefferson County population remains the largest population in the state, abundance at the Jefferson County translocation wetland is likely low, and the Hampshire County population is likely stable.

Southeastern United States.—A study in North Carolina evaluated a Spotted Turtle population located in a reconfigured landscape with heavy historical anthropogenic influence and found a healthy, robust population (O'Bryan et al. 2016). Authors concluded that the species has sufficient behavioral plasticity to survive if the landscape still provides functional resources.

A four-year study (1999 to 2003) by Litzgus and Mousseau (2004*a*) at a South Carolina site also provided evidence of a stable population. Multiple age classes were present, as well as an equal sex ratio and a decent proportion of juveniles. This population was considered to be relatively undisturbed by anthropogenic effects. This population was sampled again in 2019 as part of the C-SWG effort, and turtles were found inhabiting the same areas that were originally surveyed as well as other wetlands on the same property.

Georgia and Florida have no available population trend studies, but Stevenson et al. (2015) did evaluate the distribution of Spotted Turtles in Georgia. Two sites in Georgia have been annually surveyed since 2014 (Chandler, unpublished data). While a formal demographic analysis has not been completed, all age classes are present in both populations, and female turtles at both sites have been documented reproducing in recent years (Chandler et al. 2022). The total population size appears significantly different between the two sites. At one site, 104 individuals have been marked, while just 40 individuals have been captured in the other population. Finally, at another site sampled during the C-SWG project, Spotted Turtles were identified inhabiting a series of wetlands that had been ditched and mostly drained. It is not known what effect this has had on the population but suggests Spotted Turtle populations in the southeast are being impacted by wetland modification, even on protected lands. Overall, more population monitoring data is needed in Georgia to better understand the status of Spotted Turtles across the variety of wetland types that they inhabit in the state.

From the limited population trend information available, there is documented population decline at sites in a variety of contexts and habitats across the species range, and there are also many robust and stable populations. Additional information about population parameters and how they vary over space and time, as well as more long-term demographic data are necessary to assess viability over time. Results from sampling that occurred as part of this conservation planning effort (presented in Part III of this document) can be used as a baseline to assess change over time and complement the studies presented in this Chapter.

Population Genetics

Population genetics analyses can be a helpful tool when evaluating the fitness, diversity, distinctiveness, connectivity, and/or structure of populations to support conservation plans. Specifically, these analyses focus on genetic diversity, gene flow, migration rates, population structure, and fragmentation (Jones et al. 2018). Population genetics can provide tools for mitigating low genetic diversity (Davy and Murphy 2014), as environmental and anthropogenic disturbances pose a higher risk to populations with a small gene pool (Anthonysamy et al. 2017).

The majority of genetic research on Spotted Turtles has focused on genetic diversity (Davy 2013; Anthonysamy et al. 2017; Buchanan et al. 2019*b*). Differences in Spotted Turtle genetic diversity are dependent on region, population, and connectivity to other populations, which allows for gene flow (Davy and Murphy 2014; Anthonysamy et al. 2017; Buchanan et al. 2019*a*). Although Spotted Turtle populations can be small and isolated, Davy and Murphy (2014) found populations with high retention of genetic diversity among populations in Ontario, Canada. In addition, Spotted Turtle populations in Ontario did not show typical correlation between genetic diversity and population size (Davy 2013). Buchanan et al. (2019*a*) found Spotted Turtles in Rhode Island to have comparable genetic diversity to the more abundant Painted Turtle (*Chrysemys picta*), with evidence of low levels of inbreeding and population decline. Populations of Spotted Turtles in the Great Lakes region were found to have decreased levels of both genetic diversity and gene flow when compared to Painted Turtles (Parker and Whiteman 1993; Anthonysamy et al. 2017) and Snapping Turtles (*Chelydra serpentina*; Anthonysamy et al. 2017).

Additional population genetic analysis on Spotted Turtles have focused on potential for a bottleneck effect (decrease in gene pool due to increased genetic drift), evidence of inbreeding, risk of genetic drift, and how landscape features can alter a population's genetic structure (Davy 2013; Davy and Murphy 2014; Anthonysamy et al. 2017). Because gene flow was lower in Spotted Turtles compared to both Painted and Snapping Turtles, they may be at a higher risk for genetic drift, which is believed to be due to decreased mobility and lower dispersal capacity (Parker and Whiteman 1993; Davy 2013; Anthonysamy et al. 2017). Further, Spotted Turtles across the Great Lakes and East Coast regions are at a high risk of inbreeding when population sizes are small, causing a bottleneck effect (Davy 2013; Davy and Murphy 2013). Allopatric barriers, both anthropogenic (roads, trains, etc.) and natural, might restrict gene flow in Spotted Turtles, as it does in Wood Turtles (*Glyptemys insculpta*); however, the extent is unknown (Davy 2013; Anthonysamy et al. 2017; Robillard et al. 2019). Additional genetic studies are needed throughout the range of Spotted Turtles to better understand their genetic structure and vulnerabilities.

Threats

There are many factors that threaten the survival of Spotted Turtle populations (Milam and Melvin 2001; Lewis et al. 2004; Mitchell and Buhlmann 2007). These include habitat loss and fragmentation and associated effects (including lack of connectivity between wetlands and nesting resources), collection for the pet trade, depredation and disease, climate change, wetland change and succession, and hydrology changes due to groundwater depletion, beaver activity, and other sources. Here we summarize information from the literature, and we expand upon the primary threats using new analyses in Part IV of this document.

Expert Evaluation of Threats

We conducted a targeted survey of Spotted Turtle experts throughout the eastern United States between January and April 2019 (Appendix 1-A). Experts were asked to evaluate a list of potential threats to Spotted Turtle populations, scoring each threat from 1 (very low) to 5 (very high). We received 23 responses with at least one response from each eastern state. Respondents reported an average of 11 years of experience studying Spotted Turtle populations. Experts reported that the highest-ranked threats were as follows: development, habitat loss, and roads. Other high-ranking threats included: human-subsidized depredation, collection/poaching, lack of connectivity, lack of distributional information, and altered hydrology. The lowest-ranked threats were beaver activity and invasive plants (Figure 4-1). The most commonly referenced invasive plant of concern was common reed (*Phragmites australis*), listed by nine of the 23 (39%) respondents. Experts reported uncertainty about the effects of climate change, and over 50% of respondents noted uncertainty regarding the effects of climate change on Spotted Turtle populations. Additional threats that were listed by experts in response to an open-ended question included ecological successional changes, water quality (pollution and sedimentation), lack of public awareness, and insufficient regulation. The most urgent areas of research and study were improving distributional information and obtaining better population size and trend data, with 13 of 23 (57%) respondents identifying these gaps.

Habitat Loss, Degradation, and Fragmentation

Habitat loss in the form of wetland loss (via filling, draining, dredging, developing, and fragmenting wetlands for centuries) has been a major factor throughout the eastern United States. Altering the hydrology of a wetland may cause the system to dry out and become too shallow, or inversely become too deep for Spotted Turtles (O'Dell 2021). Invasive plant species such as Common Reed (*Phragmites* sp.), Purple Loosestrife (*Lythrum salicaria*), and Glossy Buckthorn (*Rhamnus frangula*)—as well as native species such as Red Maple (*Acer rubrum*)—may alter the structure of wetland vegetation, which may cause individuals to seek out more suitable habitat (Blossey et al. 2020; Angoh et al. 2021). Climate change and changes in land use may cause all of these to become more hazardous to populations.

In addition to direct habitat loss, fragmentation is also occurring, which has myriad effects on populations. For instance, Spotted Turtles are known to experience mortality while attempting to cross roads. In southern Maine, roads appear to be a significant threat to the persistence of Spotted Turtle populations, with all populations studied by Beaudry et al. (2008) having a 30% or greater probability of experiencing a >50% decline in population size over the next 100 yrs. Additional documentation of the impact of roads on Spotted Turtle populations are needed (Beaudry et al. 2010*b*; Seburn 2012; Howell and Seigel 2019). We further assess the magnitude of habitat loss and fragmentation on Spotted Turtle populations in Part IV of this Plan.

Collection

Collection for the pet trade was identified by experts as the most important threat to Spotted Turtle populations after habitat loss and fragmentation and associated effects (Appendix 1-A). The magnitude of this threat and how much illegal collection is affecting North American turtle populations is still largely unknown. However, it has become clear in recent years that the impact to populations could be substantial. We compiled available information to try to assess the magnitude of the threat to Spotted Turtle populations and describe ongoing efforts to minimize it.

There have been at least 11 major cases in the United States involving the confiscation of 11,892 turtles from May 2018 through December 2020 (Figure 1-1). Spotted Turtles were found among the confiscated turtles in four of these cases. This evidence indicates that the threat of illegal collection of many North American turtle species, including the Spotted Turtle, has been on the rise in recent years. This increased threat prompted a Call to Action Letter that was released on World Turtle Day

(May 23) 2020. It was drafted and/or endorsed by 37 conservation organizations and signed by 887 individuals, including many turtle experts. Actions identified in the letter include: coordinating state regulations, providing additional resources for wildlife law enforcement, providing resources for emergency housing and care of confiscated turtles, enhancing public outreach, and implementing science-based planning.

Figure 1-1. Cases of illegal trade in turtles in the United States from May 2018–December 2020 (CCITT 2021).

Price Trends.—To assess the availability and demand for Spotted Turtles in the pet trade over decades we examined price data. This information might shed light into the relative availability of this species compared to other related taxa, and how that availability may have changed over time. Spotted Turtles have been regularly available in commercial markets for at least 50 years (Connecticut Valley Biological Supply 1962; 1964), initially as a biological supply animal and eventually as a pet species (e.g., kingsnake.com 1998–2021; Glades Herp 1998–2013).

Early price data for the Spotted Turtle suggests that the species was relatively easy to obtain in the wild. For example, the materials catalogs from Connecticut Valley Biological Supply Co. from 1962–1965 (op. cit.) lists "TURTLES. Small. *Clemmys guttata*, *Chrysemys picta*, or other species. Carapace 4 to 6 inches" for $1.50 each, or roughly the equivalent of $13.81 in 2021. This was less than the 1964 price per spadefoot (*Scaphiopus holbrookii*, $2.50) or an adult pigeon ($2.00) or a "clump" of frog eggs ($3.00) in 1962. Moreover, because the species was grouped with *Chrysemys picta*, it indicates there was no special interest in Spotted Turtles, specifically. By the late 1990s (1998–2000), when internet price lists were regularly archived, the price per adult Spotted Turtle had climbed to $125.00–$250.00, roughly the equivalent of $213.15–$403.52 in 2021. These prices held remarkably consistent through to the present day. In real dollars (price adjusted for inflation), adult Spotted Turtles sold domestically in the United States from 2001–2010 averaged $333.62 per adult; and from 2011–present averaged $336.85 per adult. However, many of these animals were specifically listed as males, which fetch lower prices than adult females. One adult female was listed on faunaclassifieds.com in 2005 for $500.00, the equivalent of $711.59 in 2021. The average real price per adult (adjusted for inflation) from 1998–2021, $330.48, was 24.25 times the real price in 1962–1965, which may suggest a regional decline in availability (or ease of collection) between 1965–1998, likely exacerbated by increased demand.

Trade and Trafficking.—To assess the potential effects that trade and trafficking may have on Spotted Turtle populations, we examined available data from The Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES), USFWS Law Enforcement Management Information System (LEMIS), and other sources to estimate the magnitude and geographic scope of the threat.

CITES is an international agreement between governments to control the international trade of certain species considered threatened by overexploitation. It is composed of three Appendices: (I) species that are currently threatened with extinction, (II) species that could be threatened if trade of the species in not controlled, and (III) species that are protected in at least one country that has requested assistance from other CITES parties to control trade of the species (CITES 1973). As of 2022, over 38,000 species were listed within CITES (UNEP-WCMC 2022*a*). Approximately 16% of all listed species were animals and 16% of those species were reptiles (UNEP-WCMC 2022*a*). Testudines comprised about 19% of listed reptile species (n=184) and the majority (n=121) of these species were listed in Appendix II (UNEP-WCMC 2022*a*).

At the 11th Conference of the Parties in 2000, the United States proposed that the Spotted Turtle be added to Appendix II of CITES. In the proposal they reported that the U.S. Fish and Wildlife Service (USFWS), Division of Law Enforcement recorded 196 declared imports of Spotted Turtle individuals to the United States and 1,203 exports from 1995 to 1999 (CITES 2000*a*). However, the proposal was rejected on the basis that the proposal did not convince that trade of Spotted Turtles was international rather than domestic (CITES 2000*b*).

At the 16th Conference of the Parties, the United States again proposed that the Spotted Turtle be added to Appendix II. In this proposal they reported 727 export shipments of 7,881 Spotted Turtles from the United States from 1999 to 2010 (CITES 2013, Table 1-1). Of these exports, 16% were reported as wild and 80% were reported as captive-bred (CITES 2013). Additional examples of illegal international trade were also provided (see next section). This proposal was accepted, and the Spotted Turtle was added to Appendix II of CITES.

Table 1-1. The number of Spotted Turtle export shipments and individuals declared from 1999 to 2010. Data obtained from USFWS Law Enforcement Management Information System (LEMIS, CITES 2013).

Year	# Individuals	# Shipments
1999	344	37
2000	617	66
2001	407	64
2002	342	52
2003	358	43
2004	537	74
2005	638	66
2006	611	61
2007	653	73
2008	943	64
2009	1,442	72
2010	989	55
Total	7,881	727

Documented trafficking before CITES listing

Pre-2000.—In the first proposal to include Spotted Turtles in Appendix II, a case from 1998 was cited in which federal agents confiscated 28 illegally obtained Spotted Turtles from a home in Pennsylvania (CITES 2000*a*). The defendant involved had been observed selling turtles illegally prior to this raid and subsequent arrest (CITES 2000*a*). The proposal included additional anecdotal records of illegal Spotted Turtle collection in New York, Pennsylvania, Virginia, Michigan, North Carolina, and Ontario, Canada (CITES 2000*a*).

2000–2013.—The accepted 2013 proposal to list Spotted Turtles in Appendix II included several international examples of the illegal sale and trafficking of Spotted Turtles. From 2006−2008 up to 10 Spotted Turtles were sold at a pet market in China, in 2008 a Florida reptile dealer was arrested by North Carolina Wildlife Enforcement officers while collecting Spotted Turtles for the pet trade in Japan, and two men were arrested in Ontario, Canada in 2008, one for the unlawful possession of turtles (including Spotted Turtles), and another for illegally selling at-risk species (including Spotted Turtles) across the Canada-United States border (CITES 2013). In 2010, a man in Ontario was convicted for charges related to the sale of native turtles (including Spotted Turtles) and following an operation by the New York State Department of Environmental Conservation, 30 individuals and companies were charged in the United States with the illegal sale of wildlife, including Spotted Turtles (CITES 2013). Finally, in 2011, a Pennsylvania man was convicted on charges of illegally selling 13 Spotted Turtles (CITES 2013).

Trade following CITES listing.—To track the international trade of Spotted Turtles following their listing in Appendix II of CITES, we downloaded information from the CITES Trade database

(UNEP-WCMC 2022*b*). We searched for all cases of "*Clemmys guttata*" from 1975 to 2022, which returned 99 cases of Spotted Turtle imports and exports from 2013–2020. Of these cases, trade of live Spotted Turtles was reported in 98 cases with 1,393 Spotted Turtles reported by importers and 2,006 reported by exporters (Table 1-2). The United States exported 44% of these turtles and Hong Kong imported nearly 92% of all traded turtles.

Of the 98 cases of live turtles traded, 87 were for commercial purposes with 63 of these cases declaring the turtles were bred in captivity, 19 cases declaring the turtles were bred in captivity but did not meet CITES definition of captive-bred, one case was of pre-convention specimens, and four cases were of confiscated turtles. The United States reported the export of 109 confiscated turtles to Hong Kong in 2017 and the import of 19 confiscated turtles from Hong Kong between 2017 and 2018.

Of the remaining cases of live turtles traded, nine were the import/export of live turtles for personal purposes, one was for breeding purposes, one was for zoo purposes, and one was for law enforcement purposes. The law enforcement case involved the export of 12 Spotted Turtles from Canada to the United States in 2014. The final case, which did not involve live Spotted Turtles, was from 2020 and involved 108 wild "specimens" exported from Canada to the United States for scientific reasons.

Table 1-2. The number of reported live Spotted Turtle specimens reported by import and export countries, and the name of the associated countries. Data is from the CITES Trade Database and contains data on trade from 2013 to 2020.

Country		Reported # Specimens	
Export	**Import**	**Export**	**Import**
Canada	United States	15	0
China	Japan	3	0
Czech Republic	Japan	2	2
Germany	China	360	0
	Hong Kong	0	347
	Japan	28	12
	Republic of Korea	2	2
	Switzerland	31	3
	Taiwan	237	0
Hong Kong	Kuwait	2	0
	United States	0	19
Italy	China	164	0
	Hong Kong	0	164
Japan	Hong Kong	4	0
Netherlands	Republic of Korea	6	9
	Taiwan	98	0
Spain	Hong Kong	4	4
Switzerland	Germany	38	35
	Hong Kong	125	125
	Japan	8	0
Taiwan	United States	0	3
United States	Austria	1	0
	Hong Kong	742	638
	Indonesia	23	0
	Japan	30	30
	Taiwan	83	0
CITES Total		**2,006**	**1,393**

Federal Law Enforcement

LEMIS.—We also downloaded data from the R package "lemis" (Eskew et al. 2020), which provides access to the USFWS Law Enforcement Management Information System (LEMIS) data on wildlife imports from 2000–2014. We subset all LEMIS data to cases with "turtle" as a generic name, resulting in 7,991 cases. Of those cases, 59 were of *Clemmys* species, and five were of Spotted Turtles (2003–2012). The remaining *Clemmys* cases appeared to represent records using the former classifications for Wood, Bog, and Western Pond Turtles.

The five Spotted Turtle cases represented 62 live specimens intended for commercial activity. Four of these cases were exported from the United States to Japan and the other was exported from the United States to Taiwan. All cases were labeled as "cleared" by customs. Both proposals by the

United States for the addition of the Spotted Turtle to Appendix II in CITES included many more examples of Spotted Turtle trade from the LEMIS database, so we are unsure why so few records appeared within our search.

Annual Reports.—The USFWS Office of Law Enforcement (OLE) releases annual reports, which we searched to find recorded cases of Spotted Turtle trafficking. To the best of our knowledge, reference to Spotted Turtles specifically (as opposed to "turtles") do not occur in these reports until after the Spotted Turtle was listed in Appendix II. We searched annual reports from 2010–2019 (the most recent we found) for cases involving Spotted Turtles but could not find reference to the species from 2010−2013 or 2019; additionally, we could not locate annual reports from 2014 or 2017. The 2015 USFWS-OLE report summarized one case involving Spotted Turtles in which a New Jersey man was sentenced for the illegal take and interstate trafficking of Spotted, Wood, and Eastern Box Turtles (USFWS Office of Law Enforcement 2016). The man advertised turtles for sale online and then shipped turtles to purchasers in New York; several individuals died in transit (USFWS Office of Law Enforcement 2016). The 2016 report summarized a case in which 15 people were convicted for the unlawful collection, transportation, sale, and receipt of a variety of herptile species, including Spotted Turtles, collected in Pennsylvania, West Virginia, and New Jersey (USFWS Office of Law Enforcement 2017). These convictions followed a multi-year investigation. The 2018 report included summaries of several cases of turtle poaching and smuggling including a case in Missouri where Eastern Box and Spotted Turtles were being smuggled from Midwestern states to Hong Kong. In another case two East China Airlines flight crew members were apprehended at the Los Angeles airport when TSA discovered 31 live Spotted Turtles and 14 Box Turtles hidden in their carry-on bags. In a third case, also in Los Angeles, 152 live Box, Spotted, Map, and Wood Turtle species were discovered in an illegal export which were falsely declared. (USFWS Office of Law Enforcement 2020).

Additional Cases of Illegal Sale.—We searched The United States Department of Justice website for more recent records of Spotted Turtle trafficking and found press releases for about five cases dating from 2015 to 2022. We found two cases from 2015, one where two men were sentenced in South Carolina for the trafficking of Spotted Turtles (U.S. Attorney's Office District of South Carolina 2015) and another where a New Jersey man was sentenced for conspiring to traffic several turtle species, including Spotted Turtles, from 2011 to 2014 (U.S. Attorney's Office District of New Jersey 2015). This is the same case as was outlined in the USFWS OLE annual report from 2015.

There was one case from 2019 where a Chinese national pleaded guilty for directing a scheme where hundreds of turtles were smuggled from the United States to China (U.S. Attorney's Office District of Oregon 2019). From 2017 to 2018, he directed a co-conspirator in Oregon to purchase turtles, including 20 Spotted Turtles, from dealers across the United States (U.S. Attorney's Office District of Oregon 2019). In 2021, the co-conspirator in this case pleaded guilty for his role in purchasing hundreds of turtles and smuggling them through the United States mail system and commercial flights to China (U.S. Attorney's Office District of Oregon 2021). According to this press release 220 Spotted Turtles were involved, rather than 20 (U.S. Attorney's Office District of Oregon 2021).

In 2020, a Chinese citizen was extradited to the United States after being charged in 2019 with financing a nationwide ring of individuals smuggling turtles from the United States to Hong Kong (Department of Justice Office of Public Affairs 2020). From 2017 to 2018, this individual purchased turtles from United States sellers advertising online and arranged for them to be smuggled to Hong Kong via middlemen spread across five different states who re-packaged and falsely labeled the turtles for transport (Dept. of Justice Office of Public Affairs 2020). Finally, in 2022, a Florida reptile dealer was sentenced for shipping 16 Spotted Turtles from Georgia to Florida to be trafficked to China in 2018 (U.S. Attorney's Office Middle District of Georgia 2022).

From a review of these databases and specific cases, it is clear that the trade and trafficking of wild Spotted Turtles is occurring across a broad-scale and in large enough numbers to potentially influence population viability. These data support the opinion of Spotted Turtle professionals during the 2019 surveys presented in Appendix 1-A that collection is the second greatest threat to Spotted Turtle populations behind habitat loss and fragmentation and associated effects. Given the potential for collection to influence Spotted Turtle populations, additional information is necessary to further quantify the scale of the threat and to identify areas and sites that are most vulnerable. In the absence of that information, the Collaborative to Combat the Illegal Trade in Turtles (CCITT) was formed in 2018 with a mission to "advance efforts to better understand, prevent, and eliminate the illegal collection and trade of North America's native turtles." CCITT is an organization of state, federal, and tribal agency personnel, along with experts from non-governmental organizations and academia who are undertaking a variety of actions to further their mission.

Specific Threats to Young Age Classes

Spotted Turtles are a long-lived, iteroparous species with low egg or hatchling survival; and threats to adult classes can have the most profound effect upon populations (Enneson and Litzgus 2008). However, there are a number of threats to nests, hatchlings, and juveniles, as well. A combination of land-use changes and the removal of apex predators in North America has resulted in an increased abundance of omnivorous mesopredators (e.g., racoon, skunk, fox), many of which will opportunistically prey upon turtle nests (Marchand and Litvaitis 2004; Carlin 2017; Bougie et al. 2020). A variety of other threats such as tidal inundation, drought, and depredation by insects have all been documented to cause mortality in freshwater turtle nests and may also influence the survival of Spotted Turtle nests.

Disease

There are three primary types of infectious disease that are known to affect turtles in the eastern United States: *Ranavirus*, *Herpesvirus*, and *Mycoplasma*. Ranavirus is the most virulent of the three. It causes upper respiratory infection and results in nasal and ocular discharge, white plaques inside the mouth, lethargic behavior, and often death within two to three weeks' time. Symptoms may be similar to those of other infections, making it difficult to diagnose without performing PCR analysis to identify the virus DNA. Treatments tried to date have not been very effective. Unfortunately, infected survivors will continue to be carriers, shedding the disease, which can live for a long time in water and soil (Allender 2021).

Herpesvirus is less of a threat; to date, no outbreaks have been reported for wild Spotted Turtles or any other wild freshwater turtle (Allender 2021). One study found novel herpesviruses for several of the Emydid species, including one infecting Spotted Turtle (Ossiboff et al. 2015*a*). There was a very low infection rate with only one of 17 wild Spotted Turtles evaluated being infected. While it can cause high rates of mortality in captive turtles, it is ubiquitous in nature and is not considered a conservation concern for wild turtle population (Allender 2021). However, cross species transmission of a herpesvirus may result in mortality (Ossiboff et al. 2015*b*).

Mycoplasma is spread through direct contact with an infected turtle and transmission in wild turtles is unlikely (Allender 2021). A general health and physical examination of 30 Spotted Turtles was conducted in Massachusetts where no evidence of *Mycoplasma* spp., adenoviruses, or herpesviruses were detected (Vincent et al., unpublished data). There is some evidence to suggest co-infections of multiple diseases may provide some protection, at least in Box Turtles, with higher mortality observed in confiscated Box Turtles with one disease opposed to those that had multiple diseases (Allender 2021).

Depredation

Mesopredators, such as Northern Raccoon (*Procyon lotor*), Red Fox (*Vulpes vulpes*), Coyote (*Canis latrans*), Virginia Opossum (*Didelphis virginiana*), and Striped Skunk (*Mephitis mephitis*) are known to prey upon many freshwater turtles and their nests, including Spotted Turtles (Ernst and Lovich 2009; Wilbur 1975; Geller and Parker 2022). After the European colonization of North America, a period of market-hunting and campaigns targeted to exterminate apex predators such as Gray Wolf (*Canis lupus*) occurred (Berger 1999). This loss of apex predators resulted in a mesopredator release with mesopredators increasing in abundance (Carlin 2017; Davis et al. 2018; O'Bryan et al. 2019). Prey populations are more likely to be affected by mesopredators after mesopredator release increases their abundance (Matter and Mannan 2005).

Human population growth has also resulted in an increase of anthropogenic food sources for mesopredators (Bozek et al. 2007; Guiden et al. 2019; Heppenheimer et al. 2017; Hody and Kays 2018). Increased habitat edges due to fragmentation of habitats can also lead to increased depredation success by mesopredators because they have an increased chance of finding prey (Paton 1994; Hartley and Hunter 1998; Temple 1987). The subsidization of mesopredators and the increase in suitable and edge habitat utilized by mesopredators in North America poses a substantial threat to oviparous species (Litvaitis et al. 1996; Refsnider et al. 2022; Ritchie and Johnson 2009). A variety of field studies have documented the high depredation rates of Spotted Turtles nests (Ernst 1976). Depredation rates of Spotted Turtle nests vary among populations from 6–10% (Litzgus and Brooks

1998*a*; Refsnider et al. 2022) to 86% (Rasmussen and Litzgus 2010*a*). More information on why rates of nest depredation vary is needed to understand the effects of mesopredators on Spotted Turtle nests.

While depredation of both nests and adults can affect the persistence of turtle populations, the proportion of adults in the population likely determines the stability of Spotted Turtle populations (Feng et al. 2019*b*). Depredation of juvenile and adult turtles by mesopredators has also been documented in a variety of freshwater turtle taxa (Platt et al. 2019; Siegel 1980; Spencer and Thompson 2005; Wilbur 1975) including Spotted Turtles (E.B. Liebgold personal observation). Enneson and Litzgus (2009) noted that summer terrestrial estivation may expose individuals to an increased chance of depredation. However, Nagle et al. (2021) documented Spotted Turtles sheltering in the narrow passages of an Oak (*Quercus*) root mass and suggested this may serve as sufficient protection from mammalian depredation. Additionally, Ernst (1976) suggests that individuals may be protected from depredation once they reach a plastron length of 80mm.

Widespread field studies have also documented non-lethal results of attempted depredation of Spotted Turtles by mesopredators or have made indirect observations of adult depredation. Chandler et al. (2019; 2020) had one transmitter and one iButton temperature logger fall off an individual, which they stated was likely due to a depredation attempt. Feng et al. (2019*b*) recommended predator control at the Illinois populations they studied after finding multiple individuals missing limbs and abrasions on their shells.. Reeves and Litzgus (2008) found that 17% of the adults in an island population had missing limbs from failed depredation attempts.
.

Spotted Turtles are more terrestrially active than many other freshwater turtles, which may result in increased depredation and attempted depredation rates (Ernst 1976; Ernst and Lovich 2009; Enneson and Litzgus 2009; Rocker 2021). Mesopredator removal is one option to decrease depredation of nests and adults (Feng et al. 2019*b*). However, predator activity may not be directly correlated with depredation because mesopredators are generalists, so the abundance of other food sources and habitat type may affect depredation rates (Bartoszewicz et al. 2008; Demeny et al. 2019; Rocker 2021). Additionally, individuals may be depredated by non-mammalian predators such as other species of reptile, amphibian, and birds (DeGraff and Nein 2010). Haxton (1997) emphasized the importance of educating and working with landowners of anthropogenic Spotted Turtle sites to deter potential predators from the area

Legal Status

Spotted Turtles are of range-wide concern in the United States and Canada. Spotted Turtles are considered a "regional" species of greatest conservation need (RSGCN) in both the northeastern and southeastern regions of the United States (Therres 1999; Terwilliger Consulting, Inc. and the Northeast Fish and Wildlife Diversity Technical Committee 2013). Several states provide protection for Spotted Turtles under their state endangered species acts (Table 1-3). In addition, Spotted Turtles have been listed under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora since 2013 (CITES 2013). However, conservation organizations do not all agree on the listing status of this species. For example, the International Union for the Conservation of Nature (IUCN)'s Tortoise and Freshwater Turtle Specialist Group (TFTSG) classify Spotted Turtles as Endangered (van Dijk 2010). By contrast, NatureServe lists the Spotted Turtle G5 ("secure"; NatureServe 2016) due to their wide distribution and apparent local abundance in some jurisdictions (but acknowledges apparent decline).

Canadian populations of Spotted Turtles are listed as Endangered under the Species at Risk Act (SARA; Government of Canada 2017) Further, Spotted Turtles receive provincial protection under Ontario's Endangered Species Act (Ontario Ministry of the Environment, Conservation Parks 2019). In Québec—where the species is of questionable status —the Spotted Turtle is listed as Endangered under the *Loi sur les espèces menacées ou vulnérables* of 1989 (Act Respecting Threatened or Vulnerable Species, R.S.Q. 1989, ch. E12.01). A recovery plan has been drafted for Canadian populations (COSEWIC 2014).

Table 1-3. Legal status of Spotted Turtle (*Clemmys guttata*) in the eastern United States. Listing Status according to NatureServe (NatureServe 2016). SGCN=Species of Greatest Conservation Need. Y=Yes, N=No, L=Limited.

	ME	NH	VT	MA	RI	CT	NY	NJ	PA	DE	MD	DC	VA	WV	NC	SC	GA	FL
NatureServe rank	S2	S2	S1	S4	S5	S3	S3	S3	S3S4	S3	S3S4	S1	S4	S1	S4	S3	S3	S2S3
SGCN	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
Possession legal	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	L	Y	L
Commercial trade legal	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	L	Y	N
Import legal	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	L	Y	N
Wetland habitat protected	L	L	L	L	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Upland habitat protected	L	L	L	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

Management

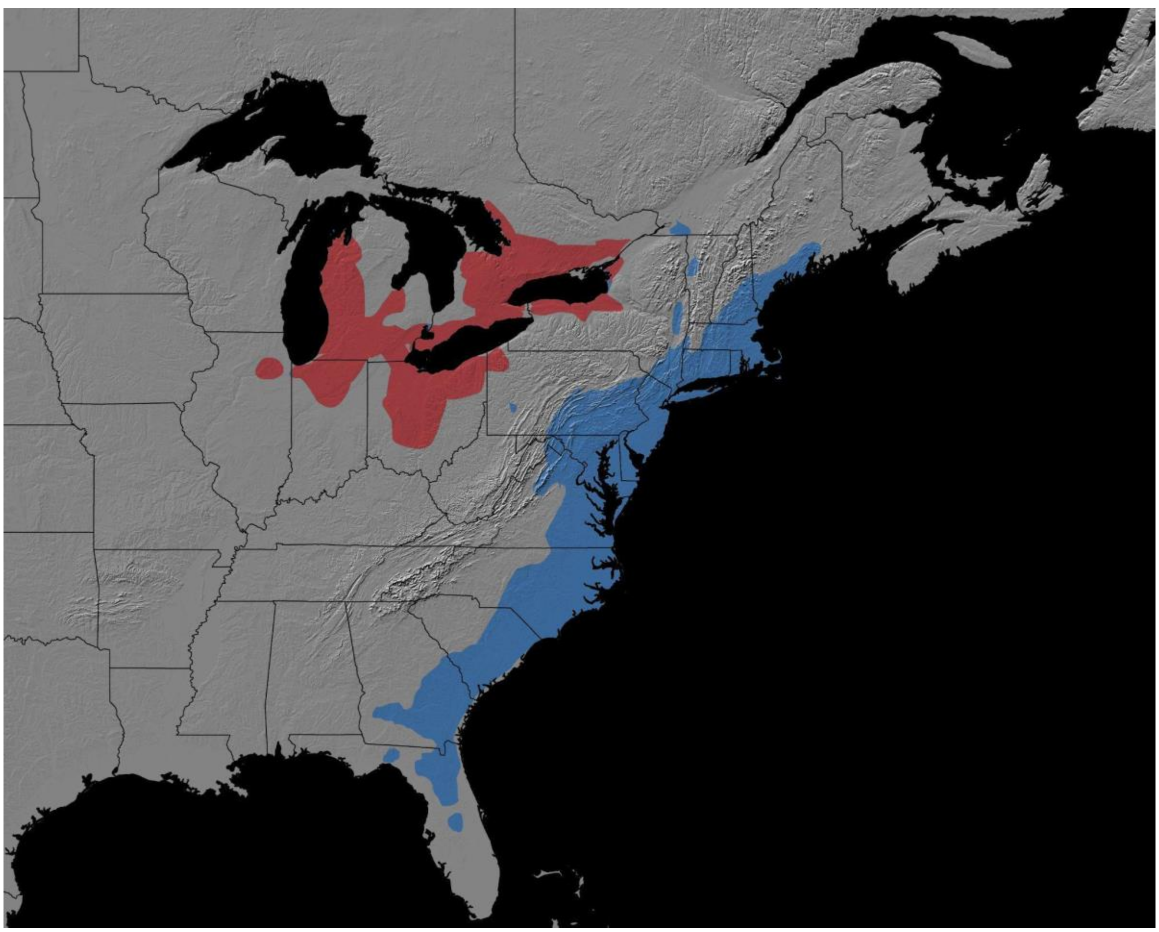
Management recommendations have been made for Spotted Turtles across their range (Lewis et al. 2004; Safi et al. 2020). Best management practices emphasizing the continued survival and health of current populations focus on habitat management (Milam and Melvin 2001; Stevenson et al. 2015; O'Dell et al. 2021) and population augmentation (Cassim 2006; Burke 2015). Habitat management can constitute the introduction of new laws or recommendations to prevent further habitat degradation (e.g., buffering high value wetlands from development) or use of beneficial practices to increase wetland and nesting habitat quality (Bol 2007; Harms 2008; Buchanan et al. 2017; Feng et al. 2019*a*). Population augmentation is the practice of capturing and captive rearing individuals to increase their fitness and chances of post release survival (Cassim 2006; Burke 2015).

Habitat protection and management practices designed to conserve populations are extensive, as the most prominent threat to Spotted Turtles is habitat loss and fragmentation (Lewis et al. 2004; Reeves and Litzgus 2008; Ernst and Lovich 2009; Safi et al. 2020). For example, studies across their distribution recommend that property managers and stakeholders protect and restore wetlands (Lewis et al. 2004; Harms 2008; Feng et al. 2019*a*) while providing protection for surrounding upland habitat (Milam and Melvin 2001; Chandler et al. 2019). Other recommendations include changing the timing of clear-cut harvesting and mowing in Spotted Turtle habitat during their inactive season (Buchanan et al. 2017), removing mesopredators if depredation rates are high (Feng et al. 2019*b*), removing invasive plants (Blossey et al. 2020), and implementing mitigation measures to decrease road mortality (Beaudry et al. 2008).

Few programs have utilized headstarting techniques to increase recruitment and population growth in Spotted Turtle populations (Burke 2015), though this technique has been successful for related species when paired with additional management plans (Tetzlaff et al. 2019; Mullin et al. 2020; Thompson et al. 2020). Cassim (2006) headstarted and repatriated Spotted Turtles into a New York population, but they experienced low survival rates due to depredation and starvation. Simulations of a population in Ontario, Canada, indicated that increasing juvenile Spotted Turtle survivorship to 100% is the best method in increasing a population's growth rate, but found headstarting and nest protection alone to not be effective methods for conservation of this species (Enneson and Litzgus 2008). Thus, additional studies are necessary to better understand the survival of post-release captive bred individuals and the effectiveness of active management techniques.

Part II. Distribution of the Spotted Turtle

Spotted Turtles range through the eastern half of the United States from east-central Maine to central Florida and in the Great Lakes region from western New York to northeastern Illinois, with populations in Ontario and possibly southern Québec (Map 2-1). The focus of this Status Assessment and Conservation Plan is the portion of the species' range in the eastern United States, from Maine to Florida. To estimate the current, historical, and potential future distribution of Spotted Turtles in this region, we undertook the following complementary assessments: (1) gathered occurrence information from existing databases and standardized field surveys; (2) delineated sites from existing occurrence data following repeatable protocols; (3) summarized the distribution of delineated sites by state, ecoregion, and watershed; and (4) developed a species distribution model trained by the occurrence data. In this section, we describe each of these methods of distributional assessment, and summarize key aspects of the species' distribution at the state level. Combined, these distribution assessments are used to assess threats influencing population persistence, detailed in Part IV.



Map 2-1. Approximate range of the Spotted Turtle (*Clemmys guttata*) in the United States and Canada. The eastern part of the species range (depicted in blue) is the primary focus of this Plan.

Chapter 2. Site Delineation

Molly K. Parren, Lisabeth L. Willey, and Cullen M. Mackenzie

Background

As part of the regional Spotted Turtle conservation planning effort, we utilized Spotted Turtle occurrence records to identify, delineate (map), attribute, rank, and select sites for inclusion in a conservation area network (CAN). The purpose of this CAN is to identify populations and landscapes that represent priorities for Spotted Turtle conservation actions. This Chapter outlines the Spotted Turtle site delineation approach and Part V (Chapters 13 & 14) further describes the development and objectives of the CAN.

Sites are intended to represent areas on the landscape that can support a population of Spotted Turtles for about the generation time of the species (25 years, van Dijk 2010) and be relatively closed on this timescale. Our goal was to ensure sites that are large enough to account for wetland and nesting area dynamics (e.g., beaver flooding and succession) over the course of decades, and therefore may represent areas larger than the currently known occupied habitat at a given site. An additional goal was to use a standardized, repeatable procedure to delineate the boundaries of sites so that they could be compared and prioritized consistently throughout the region and over time.

Methods

Occurrence Record Collection

We gathered, screened, and combined Spotted Turtle occurrence data from the entire range of the species in the eastern United States. We requested element occurrences (EOs) from each state's natural heritage program, endangered species program, and/or wildlife agency.[1] We combined those records with museum records from Global Biodiversity Information Facility, HerpMapper [HerpMapper 2020], personal datasets, nonprofit datasets, and federal records, and added observations from region-wide standardized population assessments that occurred from 2018–2021 in the context of C-SWG/RCN collaborations (see Part III). With the goal of defining habitat over the long-term and in an effort to assess potential habitat loss, the dataset included both current and historical (>30 years ago) records. The occurrence database was used to delineate sites and develop a species distribution model as described below, as well as to outline the approximate range of the species in the eastern United States for use in analyses by buffering all records in the eastern United States by 50 km and clipping by state boundaries.

Site Delineation

In total, 11,957 Spotted Turtle records were used in site delineation, and 5% of those records were historical (older than 1990; n=605; Table 2-1). Records were used to delineate sites according to the

[1] These data were generally covered by data release agreements with American Turtle Observatory.

methods described in Figure 2-1. Each Spotted Turtle record was buffered by 500 m and overlapping buffers were merged. This buffer distance was informed by NatureServe's "inferred minimum extent of habitat use when actual extent is unknown" for Spotted Turtles (Hammerson et al. 2010). Inferred extent distance typically represents the spatial requirement for a species based on the average home range but may represent the distance 75–90% of dispersing adults would move from an initial location to their ultimate destination (NatureServe 2002). Reported distances traveled by Spotted Turtles range from several meters to over one km, with average long-distance movements between 200 and 300 m (Table 2-2). Therefore, 500 m appears to be an appropriately-scaled buffer to capture the annual movements of most Spotted Turtles and the associated habitat for a single Spotted Turtle record.

Table 2-1. The count and percent of total Spotted Turtle records used for site delineation from different decades and that were current versus historical.

Time period	# Records	% Total records
Pre-1970	109	0.91%
1970s	107	0.89%
1980s	389	3.25%
1990s	1,121	9.38%
2000s	865	15.6%
2010-2017	1,502	12.56%
2018–2021 (C-SWG)	6,409	53.6%
Unknown year	455	3.81%
Total	**11,957**	**100%**
Historical (<1990)	605	5.06%
Current (>1990)	10,897	91.13%
Unknown year	455	3.81%
Total	**11,957**	**100%**

Table 2-2. Upland, inter-wetland, and nesting movement distances of Spotted Turtles (*Clemmys guttata*).

Author	Year	State	Description	Statistic	Distance (m)	SE (m)	Range (m)
Beaudry et al.	2007	ME		Mean, Median	208, 184	-	-
Beaudry et al.	2010*a*	ME	Distance to water from nest	Mean	66	-	3-283
Breisch	2006	WV	"Greatest straight-line distance between the 2 farthest points in the home ranges"	Mean	145.9	63.7	77-288
Buchanan et al.	2017	RI	Distance from nearest wetland	Mean	7.56	5.42	0.1-33.4
Hammerson et al.	2010	NH	Distance from overwintering site to a seasonal pool	Approx.	300	-	-
Chandler et al.	2019	GA	Movement from dry swamp to small pool	Mean	281	-	219-404
Chandler et al.	2022	GA	Straight line distance movements to nesting locations	Mean	97.5	-	2-491
Ernst	1976	PA	Distance from water: mating season	Maximum	250 (m)	-	-
Ernst	1976	PA	Distance from water: nesting season	Maximum	50 (f)	-	-
Ernst	1976	PA	Movements from hibernacula in pools in surrounding pastures back to the marsh	Maximum	220	-	60-220
Graham	1995	MA	Distance between hibernation sites and vernal pools	Approx.	120	-	-
Haxton and Berrill	1999	NA (Ontario)	Typical distance to wetland (when not nesting or "migrating")	Maximum	2	-	-
Joyal et al.	2001	ME	Straight line distance between wetlands	Mean	311	272	110-1150
Joyal et al.	2001	ME	Straight line distance wetland to nest	Mean	247	169	70-570
Lewis and Faulhaber	1999	OH	"Maximum turtle movements from a source area"	Mean	154.6	-	up to 731
Milam and Melvin	2001	MA	Greatest distance traveled from hibernacula	Mean, Median	265, 226	36	75-1025
Milam and Melvin	2001	MA	Distance between estivation site and permanent wetlands	Approx.	412	-	-

Author	Year	State	Description	Statistic	Distance (m)	SE (m)	Range (m)
Milam and Melvin	2001	MA	Distance between nests locations and permanent wetlands	Maximum	312		75-312
Milam and Melvin	2001	MA	Movement distance through upland habitat	Maximum	550	-	20-550
Perillo	1997	CT	Terrestrial migration distance	Maximum	265		3-265
Rasmussen and Litzgus	2010*b*	NA (Ontario)	Nest location distance from wetland	Maximum	139	-	2-139
Semlitsch and Bodie	2003	NA	Core terrestrial habitat for turtles: Mean linear radii extending outward from edge of aquatic habitats	Maximum, Minimum	287, 123	-	123-287

We then used 500 m buffers of Spotted Turtle records to select adjacent suitable wetlands using the National Wetlands Inventory (NWI; U.S. Fish & Wildlife Service 2020). Of the 11,957 Spotted Turtle records used in site delineation, 56% were within wetlands, and 89% of those records were within freshwater emergent (PEM) and forested/shrub wetlands (PFO, PSS; Table 2-3). Therefore, we selected all PEM, PFO, and PSS wetlands that intersected 500 m buffers of turtle records and included those wetlands within delineated sites.

Table 2-3. The count and percent of total Spotted Turtle records used for site delineation that were within different types of National Wetland Inventory (NWI) wetlands. In total, 50% of all Spotted Turtle records were within palustrine wetlands (freshwater emergent, forested/shrub).

NWI category	# Records	% Total records
Estuarine and Marine Deepwater	11	0.09%
Estuarine and Marine Wetland	119	1%
Freshwater Emergent Wetland	1,535	12.84%
Freshwater Forested/Shrub Wetland	4,458	37.28%
Freshwater Pond	323	2.7%
Lake	99	0.83%
Other	7	0.06%
Riverine	189	1.58%
Not in NWI wetland	5,216	43.62%
Total	**11,957**	**100%**

To ensure that we also included suitable adjacent upland habitat within sites, we also buffered wetlands by 200 m. Reported distances traveled upland by Spotted Turtles are variable with maximum distances ranging from a few meters to over a kilometer (Table 2-2). The average reported mean distances moved across all studies was 187.3 m. We rounded this value up to 200 m to capture the majority of upland movements of Spotted Turtles across their geographic range. If there were no freshwater wetlands within the 500 m buffer of a turtle record, the delineation did not change at this step.

Following input from partners, we investigated whether ditches should be incorporated into the delineation process. Unfortunately, ditches do not have their own classification within NWI, so we could not easily incorporate them. In reviewing the delineations and a subset of known ditches used by Spotted Turtles, most ditches were typically within the buffers of wetlands that were classified as habitat and therefore within a site. In cases where ditches were not within wetland buffers, they were still included in sites, if a turtle record was within 500 m.

We used the Federal Highway Administration's Highway Performance Monitoring System (HPMS) All Roads Network of Linear Referenced Data (ARNOLD, Federal Highway Administration 2018*a*) to identify roads that represented barriers to turtle movement. We considered principal arterials such as interstates, freeways, and expressways (HPMS functional classifications "f_system": 1, 2, 3) as barriers to turtle movement, and we treated them as boundaries to a site. Principal arterials are roadways with high traffic volumes, higher speed limits, and a greater number of travel lanes that carry the major portion of trips entering and leaving an activity center (Federal Highway Administration 2013). We also classified lower-ranking roads, such as minor arterials and collectors (HPMS functional classifications "f_system": 4, 5, 6, 7), as barriers if they had three or more lanes of traffic (HPMS "Through Lanes" greater than 2).

Once road barriers were identified, we then used the National Bridge Inventory (Federal Highway Administration 2018*b*) to identify any bridges that were located on a barrier road within a site that could be used as corridors by turtles between fragments of a site. If such a bridge existed, the road was not classified as a barrier. Any remaining barrier roads without bridges were then used to split sites into multiple polygons on either side of the road. Site polygons that did not contain a Spotted Turtle record and were only based on buffers were removed. Some turtle records were located on barrier roads, so those observations resulted in the inclusion of polygons on both sides of the road regardless of whether an additional record was located within the polygon. A visual depiction of the site boundaries resulting from this process is presented in Figure 2-2.

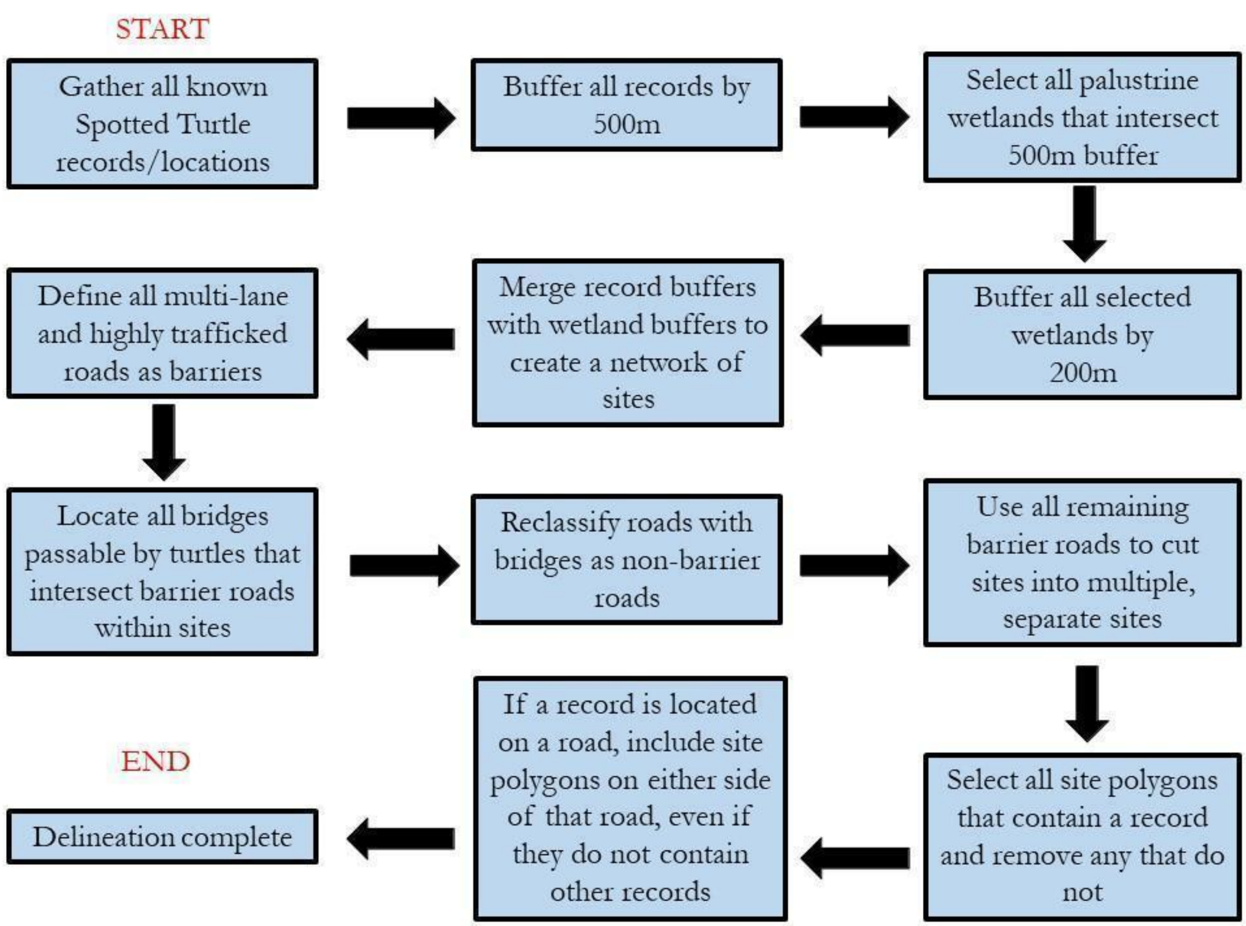


Figure 2-1. Flowchart depicting the standardized Spotted Turtle site delineation process.

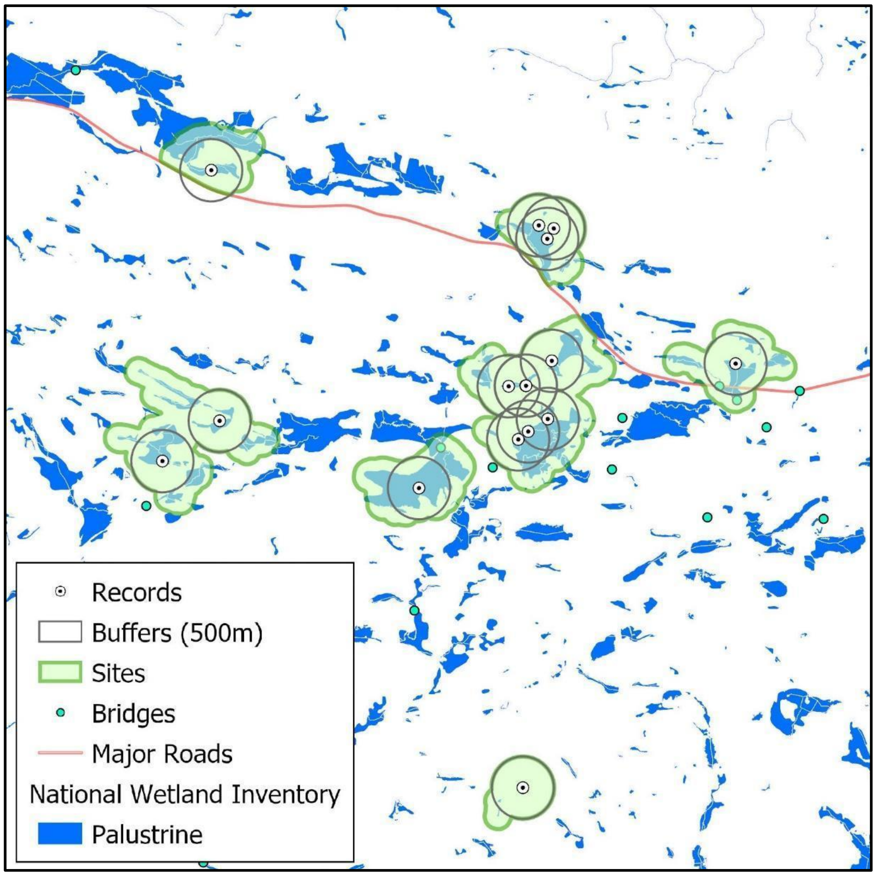


Figure 2-2. Example of site delineation. White dots represent known Spotted Turtle records, circles represent 500 m buffers of these records, blue polygons represent palustrine wetlands, red lines represent major roads that are considered barriers, teal dots represent bridges passable by turtles, and green polygons represent final site delineations.

Results

Following the standardized site delineation process, 769,079.71 hectares were mapped and classified as Spotted Turtle habitat within 2,351 sites in the eastern United States (Tables 2-4, 2-5). Sites were delineated within 17 states and the District of Columbia (Table 2-4) and intersected five Level II ecoregions and 17 Level III ecoregions (Table 2-5). The average area within a Spotted Turtle site was 327.5 hectares, and the average percent cover of wetlands within a Spotted Turtle site was 19.6%.

Massachusetts had the greatest number of Spotted Turtle sites (n=670; Map 2-2), representing 28.5% of all sites in the region and over 8.5% of the land area of the state. Pennsylvania (n=260) and North Carolina (n=233) each also had over 200 sites. Outlying occurrences occurred from Waldo County, Maine, throughout the Lakes Region of Grafton and Carroll counties, New Hampshire, and in southern Vermont, and as far south as Polk County, Florida, but sites were isolated in these regions. Isolated Spotted Turtle populations also occurred regularly on offshore islands of varying origins from mid-coast Maine to the outer banks of North Carolina, with only scattered or uncertain offshore island occurrences south of the Cape Fear River.

Table 2-4. Count, area, and percent cover of delineated Spotted Turtle sites within states.

State	# Sites	Site Area (ha)	% State area within sites
Connecticut	87	17,405.47	1.35%
Delaware	50	12,496.85	2.4%
Florida	46	35,679.51	0.24%
Georgia	126	87,747.10	0.58%
Maine	87	28,505.61	0.34%
Maryland	48	12,232.21	0.46%
Massachusetts	670	181,927.13	8.56%
New Hampshire	188	35,942.64	1.5%
New Jersey	99	31,613.35	1.57%
New York	171	38,956.43	0.31%
North Carolina	223	155,938.48	1.21%
Pennsylvania	260	37,432.93	0.32%
Rhode Island	64	13,205.34	4.64%
South Carolina	75	35,713.96	0.44%
Vermont	3	662.36	0.03%
Virginia	143	42,045.52	0.4%
District of Columbia	1	165.78	0.94%
West Virginia	10	1,409.03	0.02%
Region	**2,351**	**769,079.71**	**0.67%**

The majority (61%) and the highest density of sites were located along the Coastal Plain, in the areas designated as the Northeast Coastal Zone, the Middle Atlantic Coastal Plain, and the Atlantic Coastal Pine Barrens Level 4 Ecoregions (Map 2-3), with fewer (4.3%) in the Southern Coastal Plain south of Charleston, North Carolina. Lower densities occurred inland in the Piedmont, Ridge and Valley, and Southeastern Plains ecoregions, and few records were at higher elevations in the Appalachian Mountains, which serve as a barrier between the eastern and western portions of the species range (Map 2-1). Density of sites was also higher along the Eastern Great Lakes Lowlands and Erie Drift Plains.

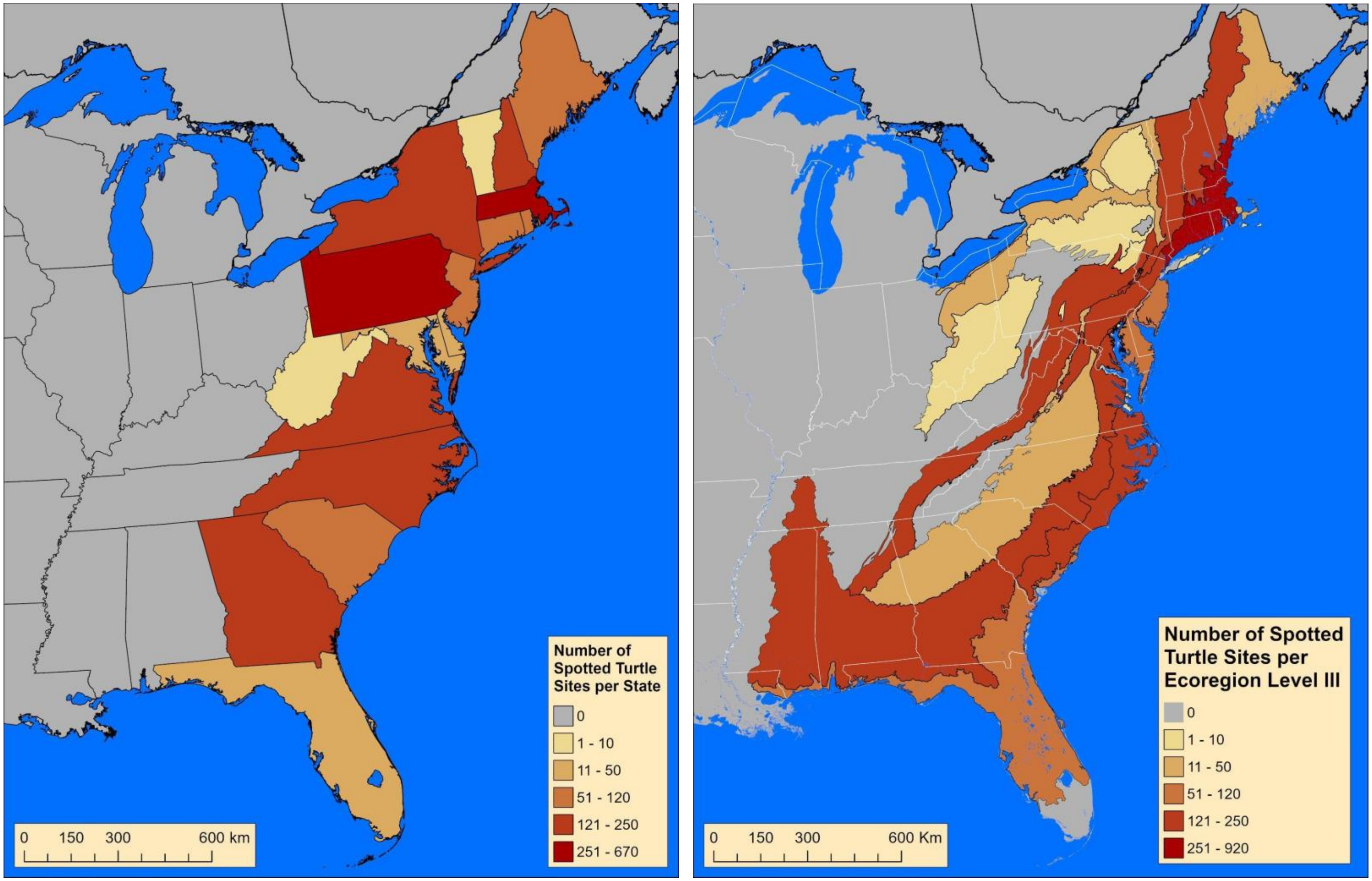
Caveats/Interpretation

The number of records within a state or ecoregion was a function of Spotted Turtle presence/abundance, accessibility for observation (which was often correlated with anthropogenic land cover), sampling effort, and the degree to which the species is tracked in a state, which is related to listing status. The number of sites was also a function of the level of fragmentation of the landscape; major roads can divide a potentially large site into multiple sites in more fragmented areas, increasing the number of sites (though not the amount of mapped habitat area). Therefore, the density of records and sites was inconsistent across the region and not necessarily representative of relative habitat quality.

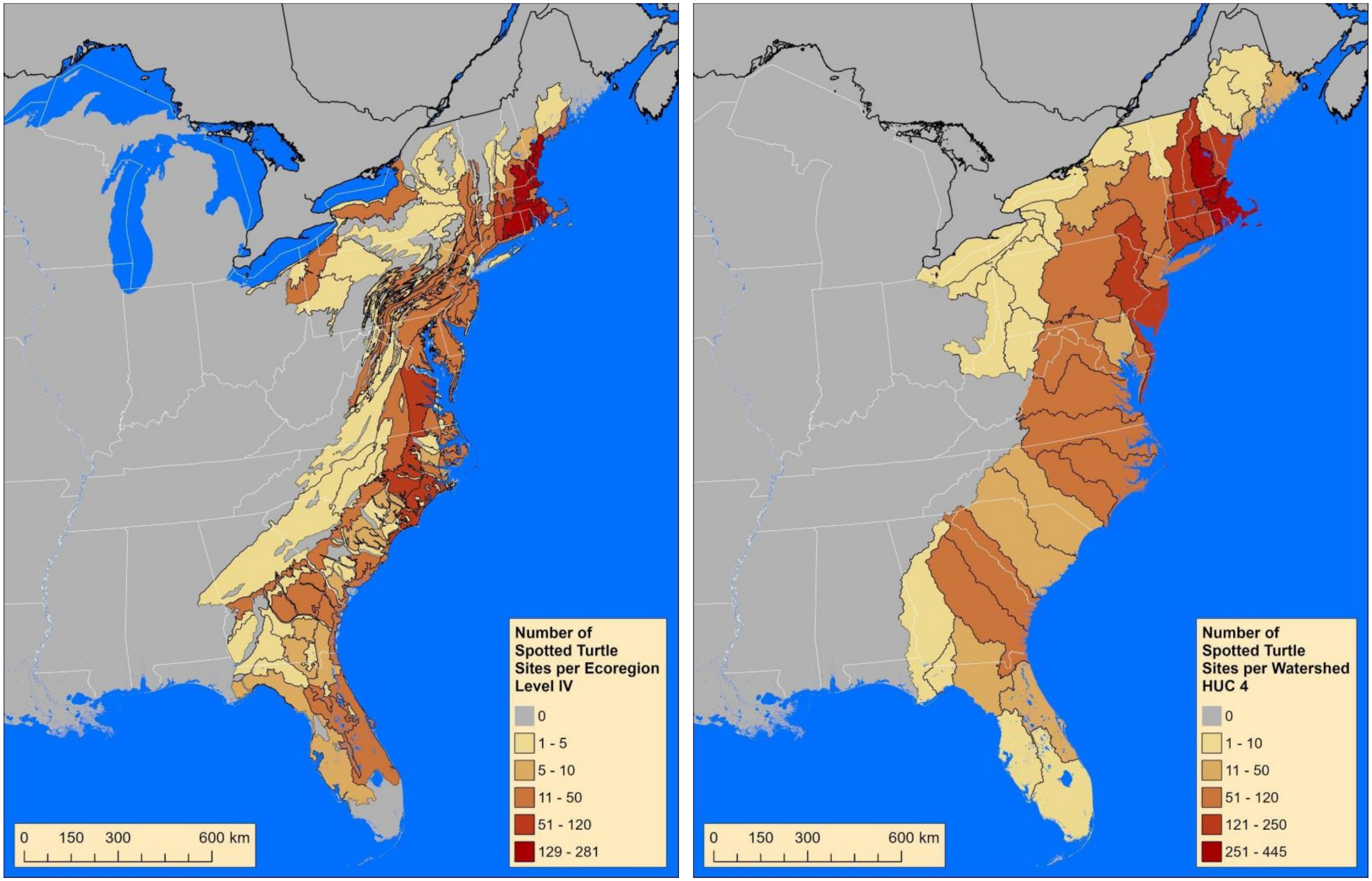
Because data quality also varies across the region for different geospatial layers, we chose to only use national data layers to avoid inconsistencies in the site delineation process, although there may be more precise local layers available. We acknowledge that railroads, impervious surfaces, and other anthropogenic features may be additional barriers to movement, but we used the site attribution and ranking process to account for the presence of these landscape attributes.

Table 2-5. Count, area, and percent cover of delineated Spotted Turtle sites within ecoregions in the eastern United States (above line = Level III Ecoregion, below line = Level II Ecoregion).

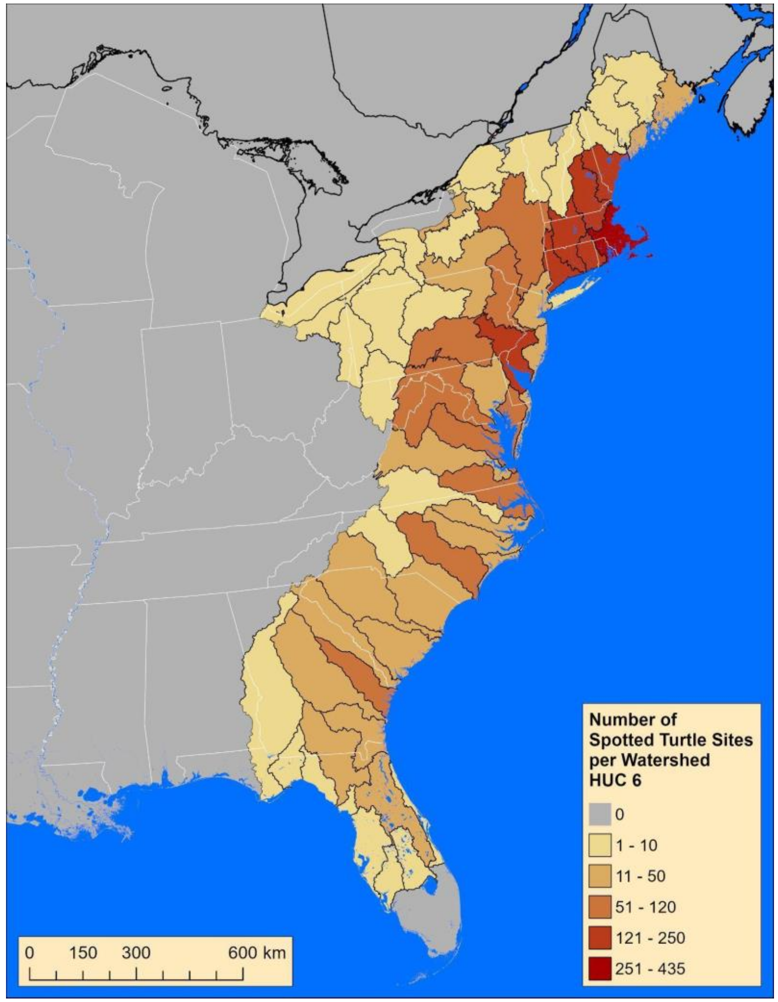
Ecoregion	# Sites	Site Area (ha)	% Ecoregion area within sites
Acadian Plains & Hills	25	4,031.86	0.09%
Atlantic Coastal Pine Barrens	142	34,529.71	2.41%
Blue Ridge	12	1,743.12	0.04%
Central Appalachians	1	191.54	0.003%
Eastern Great Lakes Lowlands	23	12,417.20	0.31%
Erie Drift Plain	14	2,975.00	0.1%
Middle Atlantic Coastal Plain	340	191,726.62	2.44%
North Central Appalachians	9	1,516.51	0.06%
Northeastern Coastal Zone	953	250,908.83	5.96%
Northern Allegheny Plateau	165	539.23	0.01%
Northern Appalachian & Atlantic Maritime Highlands	5	29,331.68	0.24%
Northern Piedmont	123	18,983.56	0.61%
Piedmont	43	7,780.63	0.05%
Ridge & Valley	181	29,169.74	0.25%
Southeastern Plains	210	107,696.85	0.33%
Southern Coastal Plain	102	73,853.17	0.52%
Western Allegheny Plateau	3	389.98	0.005%
Atlantic Highlands	174	30,848.20	0.2%
Mississippi Alluvial & Southeast USA Coastal Plains	584	300,109.50	0.86%
Mixed Wood Plains	1,020	270,872.12	0.69%
Ozark/Ouachita-Appalachian Forests	197	31,494.38	0.06%
Southeastern USA Plains	376	134,461.04	0.13%
Region	**2,351**	**769,079.71**	**0.67%**



Map 2-2. A) Number of known Spotted Turtle sites within each state (left) and B) within each Ecoregion (U.S. EPA Level 3). Ecoregion data were retrieved from the United States environmental protection agency (EPA) website.



Map 2-3. A) Number of Spotted Turtle sites within each Ecoregion (U.S. EPA Level 4, left) and B) within each Watershed (HUC 4). Ecoregion data were retrieved from the United States environmental protection agency (EPA) website and watershed data were retrieved from the USGS watershed boundary website.



Map 2-4. Number of Spotted Turtle sites within each Watershed (HUC 6). Watershed data were retrieved from the USGS watershed boundary website.

Chapter 3. Species Distribution and Habitat Suitability Modeling for the Spotted Turtle

H. Patrick Roberts and Lisabeth L. Willey

Summary

This section outlines the basic methodology used to develop the species distribution models that were incorporated into the Status Assessment and Conservation Plan for the Spotted Turtle in the eastern United States. We acquired over 5,500 records from Maine to Florida, 2,590 of which we used to develop these models. We employed an ensemble modeling approach, which incorporated the results of four different modeling approaches: generalized linear models, multiple adaptive regression splines, random forests, and boosted regression trees. We included 43 topographic, climate, soil, wetland, and landcover variables at multiple spatial scales (pixel, 90 m, 180 m, 360 m, 720 m, 1,440 m) for consideration as competing variables in model selection. We used final ensemble models to generate predictive surfaces where the value of each cell can be interpreted as a relative probability of occurrence (values are multiplied by 1,000 and range from 0 to 1,000; e.g., 0.5 probability occurrence = 500). Because these models utilized pseudo-absences rather than true absence records, we encourage users to focus on relative suitability scores within each geographic area rather than the absolute values themselves. The predictive surfaces generated from this effort are intended to aid in the identification of locations for population sampling, as well as the development of the regional Conservation Area Network.

Methods

Occurrence Records

We gathered Spotted Turtle presence locations from state natural heritage programs, state wildlife agencies, museum collections, non-profit databases, and personal data sets throughout the eastern United States from Maine to Florida (see Part II). As of spring 2019, when we began the modeling process, we had acquired over 5,500 occurrence records from 17 states and the District of Columbia within the period of 1897–2019 (this represents a subset of the final database described in Part II). Records within this dataset varied considerably in locational accuracy. Therefore, we implemented a systematic screening process to remove unreliable records. Due to existing data screening procedures within state wildlife agencies, we assumed that all state agency records were reliable within a 250-m accuracy radius unless otherwise indicated. For all records that contained supporting descriptive locality information, we cross-referenced the coordinates and descriptions to verify agreement. In cases where the veracity of records was in question and there was a known individual with first-hand knowledge of the contributing dataset, we contacted that person to clarify any concerns. We viewed the remaining records projected upon aerial imagery to identify any distributional outliers or likely errors given the landscape context of the records and life history of the species.

We only used records with an estimated 250-m radius accuracy (half the length of the separation distance and near the average home range length in Massachusetts; Milam and Melvin 2001). For analyses of contemporary habitat suitability and distribution, we only used records from 1990–2019. Once we completed the screening process, we randomly selected as many occurrence records as possible while maintaining a minimum distance of 500 m between all records using ArcGIS 10.5 (Environmental Systems Research Institute, Inc., Redlands, CA) in order to reduce spatial autocorrelation. We chose a 500 m separation distance because this distance represents a large Spotted Turtle home range length in Massachusetts (Milam and Melvin 2001). The final vetted data set used for habitat suitability modeling contained 2,590 records.

Pseudo-Absences

Using ArcGIS, we randomly generated pseudo-absences within each state at approximately 10:1 pseudo-absence-to-presence ratio. To account for substantial variation in the number of records per state, we distributed occurrences within each state proportional to the number of respective records (e.g., if one state had 50 records and another had 150, they received 500 and 1,500 pseudo-absences respectively). Because the spatial distribution of records was biased by distance to roads, we generated pseudo-absences proportionally to the relative distance of records from roads within each state (e.g., if 30 of 35 records were 0 m from roads and remaining 5 records were 25 m from roads, we randomly distributed 300 pseudo-absences throughout the state on roads and 50 pseudo-absences randomly at 25 m from roads).

Environmental Variables

We selected a suite of climate, topographic, soil, wetland, and landcover variables that we believed may influence the distribution and habitat suitability of Spotted Turtles (Table 3-1). Although Spotted Turtles select some resources at finer scales, we chose to use 90-m pixel size for all environmental data layers due to computational restrictions. Models that allow for different spatial scales among predictor variables are typically more robust than single-scale models (Johnson et al. 2004; Wheatley and Johnson 2009; Zeller et al. 2014). Therefore, we considered variables at six different scales: the individual cell, as well as 90-m, 180-m, 360-m, 720-m, and 1,440-m circular buffers. These scales reflect different aspects of Spotted Turtle movement and population ecology, including activity centers, home range, large movements, and the broader associated landscape. Climate variables included mean annual precipitation, mean April precipitation, mean July precipitation, mean accumulated growing-degree-days, mean minimum January temperature, mean July temperature, and mean maximum vapor pressure deficit. The accumulated growing degree days dataset was obtained from USA National Phenology Network (usanpn.org). We obtained the remaining climate data, which represents 30-year normals (1981–2010), from the PRISM climate group (PRISM Climate Group 2010*a*, *b*).

Topographic variables included mean elevation (National Digital Elevation Model), mean topographic roughness, mean Topographic Position Index (TPI), mean Terrain Ruggedness Index

(TRI), and distance to shore. We calculated roughness, TPI, and TRI using the "raster" package (Hijmans and van Etten 2019) in R (R Core Team 2021), which follows metric definitions described by Wilson et al. (2007). Roughness represents the largest difference between the value of a cell and one of its eight surrounding cells. TPI is the difference between the value of a cell and the mean value of its eight surrounding cells. TRI represents the mean of the absolute differences between the value of a cell and the values of its eight surrounding cells.

We derived all wetland variables from the National Wetland Inventory (NWI) database (U.S. Fish & Wildlife Service 2020). Prior to creating data layers, we first investigated what wetlands were most associated with Spotted Turtles by sampling the NWI database by state using the Spotted Turtle occurrence database. From this exploration process, it was determined that Spotted Turtle records were consistently associated with emergent, shrub, and forested wetlands. Therefore, we developed several variables relating to these wetland types. Wetland variables included percent emergent, shrub, forest, shrub/forest, emergent/shrub/forest, and all wetlands (except ocean and riverine wetlands) in order to evaluate the importance of other wetland types that are not included in the emergent, shrub, or forested group. We did not include riverine habitats in the "all wetlands" category because rivers and streams were not consistently represented when rasterized. We also considered variables representing the distance to each wetland category listed above. Lastly, we estimated two types of wetland richness: "primary wetland richness" and "regime richness." Primary wetland richness represents the number of primary wetland types as categorized by NWI (emergent, shrub, forest) within each specified spatial scale. Regime richness represents the number of different wetland hydrologic regimes present within each specified spatial scale. Wetland regimes fell into the following categories: temporarily flooded, seasonally saturated, seasonally flooded, continuously saturated, seasonally flooded/saturated, semi-permanently flooded, intermittently exposed, permanently flooded, intermittently flooded, artificially flooded.

Soil variables included saturated soil water content, residual soil water content, hydraulic conductivity, available water content, pH, percent sand, percent silt, percent clay, and percent organic matter. Each soil variable was considered for depths of 0–5 and 5–15 cm. We obtained all soil variables from the POLARIS (Chaney et al. 2016) database (Table 3-1). Landcover variables included percent canopy cover, percent imperviousness, percent developed land, road density, percent cultivated crops, percent hay/pasture, and percent agriculture (cultivated and hay/pasture combined) from the National Land Cover Database (Yang et al. 2018).

Table 3-1. Suite of variables considered for inclusion in distribution and habitat suitability models.

Variable	Source	Year	Citation
Climate			
Mean Annual Precipitation	PRISM Climate Data	1981–2010	PRISM Climate Group 2010*b*
Mean April precipitation	PRISM Climate Data	1981–2010	PRISM Climate Group 2010*b*
Mean July Precipitation	PRISM Climate Data	1981–2010	PRISM Climate Group 2010*b*
Accumulated Growing-degree-days	USA National Phenology Network		USA National Phenology Network
Minimum January Temperature	PRISM Climate Data	1981–2010	PRISM Climate Group 2010*a*
Mean July Temperature	PRISM Climate Data	1981–2010	PRISM Climate Group 2010*a*
Maximum Vapor Pressure deficit	PRISM Climate Data	1981–2010	PRISM Climate Group 2010*a*
Topography			
Elevation	National Elevation Dataset (NED)	2009?	USGS 2009
Slope	Derived from NED	2009	USGS 2009
Roughness	Derived from NED	2009	USGS 2009
Topographic Position Index	Derived from NED	2009	USGS 2009
Topographic Ruggedness Index	Derived from NED	2009	USGS 2009
Distance to Shore	Derived using ArcGIS		
Wetland			
% emergent wetland	National Wetland Inventory (NWI)	2020	USFWS 2020
% shrub wetland	NWI	2020	USFWS 2020
% forested wetland	NWI	2020	USFWS 2020
% emergent and forest/shrub wetland	NWI	2020	USFWS 2020
% forested/shrub wetland	NWI	2020	USFWS 2020
% all wetland	NWI	2020	USFWS 2020
Distance to emergent wetland	NWI	2020	USFWS 2020
Distance to shrub	NWI	2020	USFWS 2020
Distance to forest	NWI	2020	USFWS 2020
Distance to emergent, shrub, or forested wetland	NWI	2020	USFWS 2020
Distance to shrub or forested wetland	NWI	2020	USFWS 2020
Distance to all wetlands	NWI	2020	USFWS 2020
Primary wetland richness	NWI	2020	USFWS 2020
Wetland regime richness	NWI	2020	USFWS 2020
Soil			
Saturated soil water content	POLARIS	2016	Chaney et al. 2016
Residual soil water content	POLARIS	2016	Chaney et al. 2016
Percent sand	POLARIS	2016	Chaney et al. 2016
Percent silt	POLARIS	2016	Chaney et al. 2016
Percent clay	POLARIS	2016	Chaney et al. 2016
pH	POLARIS	2016	Chaney et al. 2016
Percent organic matter	POLARIS	2016	Chaney et al. 2016
Hydraulic conductivity	POLARIS	2016	Chaney et al. 2016

Variable	Source	Year	Citation
Available water content	POLARIS	2016	Chaney et al. 2016
Land Cover			
% Canopy	NLCD- Tree Canopy	2016	Coulston et al. 2012
% Agriculture	NLCD - Land Cover	2016	Yang et al. 2018
% Cultivated Crops	NLCD - Land Cover	2016	Yang et al. 2018
% Hay/Pasture	NLCD - Land Cover	2016	Yang et al. 2018
% Impervious	NLCD - Imperviousness	2016	Yang et al. 2018
% Developed	NLCD - Land Cover	2016	Yang et al. 2018
% Road	NLCD - Land Cover	2016	Yang et al. 2018

Model Building

Following Zeller et al. (2017), we conducted t-tests on presence and pseudo-absence locations for each environmental variable and scale. We removed all variables with $P > 0.01$ and chose the scale for each variable with the highest t-value. We assessed Spearman's rank correlations between all variables and removed the variable with the lower t-value for pairs of variables with $r > 0.7$.

We used the "biomod2" package (Thuiller et al. 2016) in R to create ensemble models to estimate the species distribution and habitat suitability. Ensemble models have been shown to outperform single species distribution models and may be ideal for pseudo-absence-based models (Grenouillet et al. 2011). Models contributing to the ensemble included generalized linear models, multiple adaptive regression splines, random forests, and boosted regression trees. Final models for each modeling methodology were selected automatically within the "biomod2" package. We conducted 10-fold cross validation to assess the predictive ability of each model. For each of the ten validation datasets held out, we calculated the area under the receiver operating curve as a measure of relative performance (ROC; Hanley and McNeil 1982). We used final ensemble models to project habitat suitability throughout the eastern United States, from Maine to Florida.

Product

This modeling approach resulted in a 90-m cell size raster layer of relative habitat suitability for Spotted Turtles in the eastern United States, with higher values representing greater relative habitat suitability. State-specific raster layers were provided to state-agency lead biologists. The final regional (Maine to Florida) ensemble model had an ROC (AUC) of 0.962 (cut-off = 120.5, sensitivity = 98.9, specificity = 83), suggesting sufficient predictive ability.

While this model provided a helpful foundation for assessing relative habitat suitability and identifying areas for future surveys, there are several limitations and caveats to be considered when utilizing the output. Spotted Turtle records are recorded inconsistently throughout the region, and record abundance and density does not necessarily reflect habitat suitability. In fact, in some portions of the species range, including parts of North Carolina and Virginia, the species is considered widespread and locally abundant and therefore it is not tracked by the state wildlife agency as closely as other species, and the density of northern records may have skewed model results. We recommend the continued collection of locality data to improve future models and additional habitat models with a focus on the southern extent of the species range.

In addition, it is important to note that this model was developed based on occurrence records, which represent individual Spotted Turtles rather than populations, that many of these records may be historical and therefore represent habitat associations that are no longer accurate, and that extensive amounts of wetland loss have occurred throughout the eastern United States (see Chapter 9), all factors that potentially decrease the accuracy of this suitability modeling approach. However, this model also represents the region's current understanding of the relative suitability of Spotted Turtle habitat throughout the eastern United States using the best available information available, and the AUC value of 0.962 suggests good predictive performance, enabling partners to confidently use the results to identify sampling priorities across the region and to aid in conservation prioritization when used in conjunction with on-the-ground sampling formation.

Part III. Empirical Population Assessment

Chapter 4 - Regional Sampling Protocol

Lisabeth L. Willey, Michael T. Jones, H. Patrick Roberts, Kathryn Lauer, Thomas S.B. Akre, Lori Erb, Derek Yorks, Jonathan Mays, Jessica Meck, and JD Kleopfer

As part of this status assessment and conservation planning effort, the Eastern Spotted Turtle Working Group designed a standardized monitoring protocol to implement at Spotted Turtle sites throughout the eastern part of the species' range (Maine to Florida). The protocol was designed to be relatively simple, flexible, fit within existing research programs, and accommodate regional differences in seasonal activity periods, habitat structure, and research priorities. The protocol was adapted in part from the Northeast Blanding's Turtle Sampling Protocol developed by the Northeast Blanding's Turtle Working Group (www.blandingsturtle.org) and was field-tested in Massachusetts in 2014. The protocol was refined based upon an expert poll completed by experts from Maine to Florida and was updated in 2019 based on results from 2018 sampling. The protocol is summarized here, and the complete version is available as Appendix 4-A.

Two basic methodologies are included: trap-based assessments and visual assessments without traps. Two levels of trap-based assessments—**Rapid** and **Demographic**—are described. The protocol for Rapid Assessments is simply a reduced-effort version of the Demographic Assessment protocol. A visual Rapid Assessment is also described. To summarize the protocol, observers: (1) delineate potential Spotted Turtle habitat using a geographic information system (e.g., Google Earth or ArcGIS) and recent aerial imagery; (2) place up to four 200-m radius plots centered on potential Spotted Turtle habitat with plot centroids up to 800 m apart (Figure 4-1); (3) conduct a Trap-based Rapid Assessment (TRA), Demographic Assessment (DA; trap-based), or Visual Rapid Assessment (VRA).

Trap-Based Assessment

For TRAs, five collapsible mesh minnow traps (0.3 m; trap model: ProMar TR-502 or TR-503) are placed ≥30 m apart (which represents the average daily spring movement distance of Spotted Turtles; Litzgus and Mosseau 2004*b*) within each reference plot, for a total of 20 traps at a site. Where mesopredators are common, and depredation risk is relatively high, traps lined with wire mesh (e.g., crab traps) can be used (Chandler et al. 2017; Oxenrider et al. 2019). The specific location of traps in wetlands within reference plots were determined by individual surveyors in the field. For the purposes of standardization, we encouraged surveyors to place traps in shallow (≤0.2 m) flow channels, at the edge of thick vegetation (e.g., sedges, grasses, shrubs) or structure (e.g., logs, debris), near potential basking sites, and areas with high solar exposure, because these are microhabitats known to be attractive to Spotted Turtles. Traps may be set anytime during the Spotted Turtle activity season in the local region. All traps are tethered to stakes or adjacent vegetation to prevent movement. Floatation devices (e.g., plastic bottles or foam pool noodles) are placed within traps to ensure breathing space for trapped turtles. Traps are baited with canned sardines in oil or fish-flavored wet cat food and checked every 24 hours for four consecutive days. Each turtle captured was recorded, measured, photographed, individually marked by filing notches into marginal carapace scutes according to local notching systems (e.g., Cagle 1939; Ernst et al. 1974; Nagle et al. 2017), and released. For DAs, the TRA protocol is undertaken three times (for a total of 12 nights, with 20 traps each night).

At sites with low turtle density, recapture rates, trap success, or extremely narrow sampling opportunities for detection, researchers can conduct "high density" trapping within one or more reference plots. At least one four-night run at four reference plots should occur in order to be comparable with trapping at other sites, then researchers can place 10 traps in each reference plot (in one to three plots, if necessary) for the remaining eight (or more) trap nights.

Figure 4-1. Illustration of study site delineation in Google Earth. The yellow central dots illustrate Reference Points centered on areas of suitable (or potentially suitable) Spotted Turtle habitat, surrounded by reference plots with a 200 m radius.

Visual Assessment

For VRAs, two types of assessments are possible—time constrained and unconstrained. In both cases, a single observer visits a site three times during the survey season, and during each visit, actively searches for turtles on foot. For time constrained surveys, the surveyor searches for 20 minutes per reference plot (up to 80 minutes total per visit), recording start and stop time, and location of each survey. For unconstrained surveys, the surveyor walks a meandering transect anywhere within each reference plot, for any amount of time, recording start and end time and GPS track.

As part of the C-SWG and RCN efforts, broad regional participation in the sampling was encouraged to increase the size of the representative sample. Data collected through the regional effort were compiled and maintained in a centralized database at the American Turtle Observatory (www.americanturtles.org) for pooled analysis, the results of which are presented in the following sections of this plan. For additional details on the sampling methodology, see Appendix 4-A.

Chapter 5. Summary of Regional Sampling Information

Molly K. Parren, Kathryn Lauer, and Lisabeth L. Willey

Utilizing the protocol described in Chapter 4, the Eastern Spotted Turtle Working Group implemented standardized sampling at Spotted Turtle sites throughout the eastern part of the species' range (Maine to Florida). This Chapter presents the results of that sampling effort from 2018 to 2021. Sampling data was recorded using five different data sheets: trap set, trap check, individual, VRA, and VRA individual. As a result, individual summaries may vary based on the data source. We indicate data source in Table and Figure captions.

Sampling Effort

Visual Rapid Assessments

From 2018 to 2021, 17 states and the District of Columbia (DC) sampled 309 unique sites for Spotted Turtles; 89 sites were surveyed using Visual Rapid Assessments (VRAs, Table 5-1), and 285 were trapped (Table 5-2). Occasionally a site would be sampled using both VRA and traps. VRAs were conducted by 11 states and DC at 305 reference plots (Table 5-1). The majority of VRA sampling was done in Georgia and Florida and in 2018 and 2019 (Table 5-1).

During VRAs, 121 Spotted Turtles were detected (Table 5-1); 58 were males, 46 were females, seven were juveniles, and 10 were of an unknown age and sex (Figures 5-1, 5-2). Additionally, 24 of the turtles were detected on land, 87 were detected in water, and the habitat was not provided for the remaining 10 turtles (Figures 5-1, 5-2).

Table 5-1. The number of sites and reference plots surveyed each year and within each state that conducted Visual Rapid Assessment (VRA) sampling. The number of site visits (based on site/reference/visit number) and days are also provided. Source: VRA.

Category		Sites	Reference Plots	Days	Visits	Spotted Turtles
Year	2018	35	121	61	397	57
	2019	49	170	63	472	61
	2020	5	6	5	15	1
	2021	14	47	34	129	2
State	DC	2	5	8	10	1
	DE	1	1	3	3	10
	FL	25	99	97	352	8
	GA	31	120	110	454	31
	MA	8	12	9	24	52
	MD	3	3	7	7	0
	ME	1	3	1	3	5
	NJ	1	4	1	4	0
	NY	1	1	3	3	8
	PA	1	4	1	4	1
	RI	2	8	6	17	2
	SC	13	45	38	132	3
Total		**89**	**305**	**284**	**1,013**	**121**

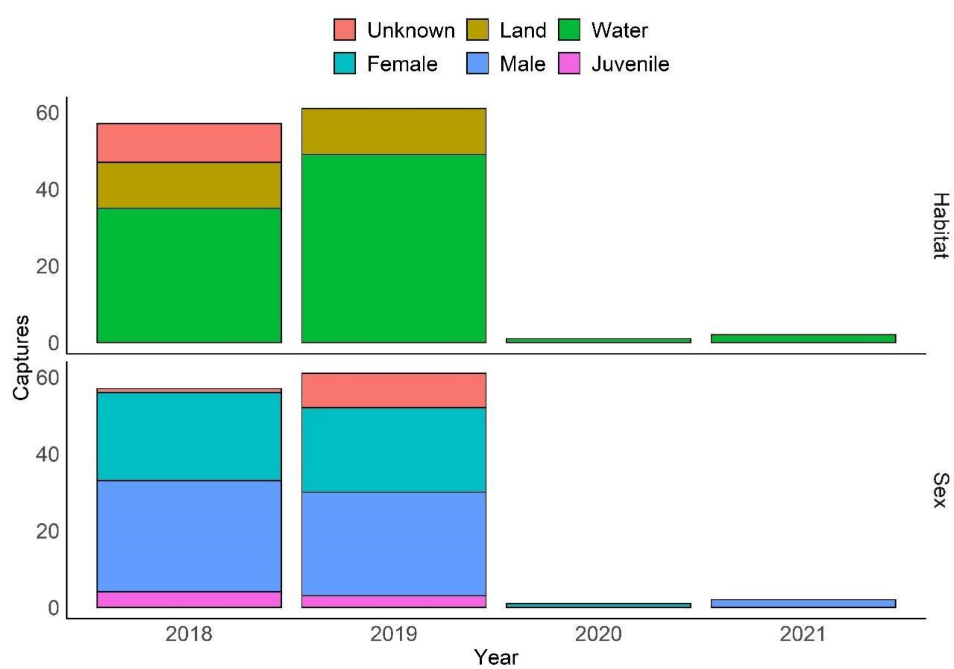


Figure 5-1. Number of Spotted Turtles captured during VRAs within each Sex/Age category and habitat category, by year surveyed. Source: VRA.

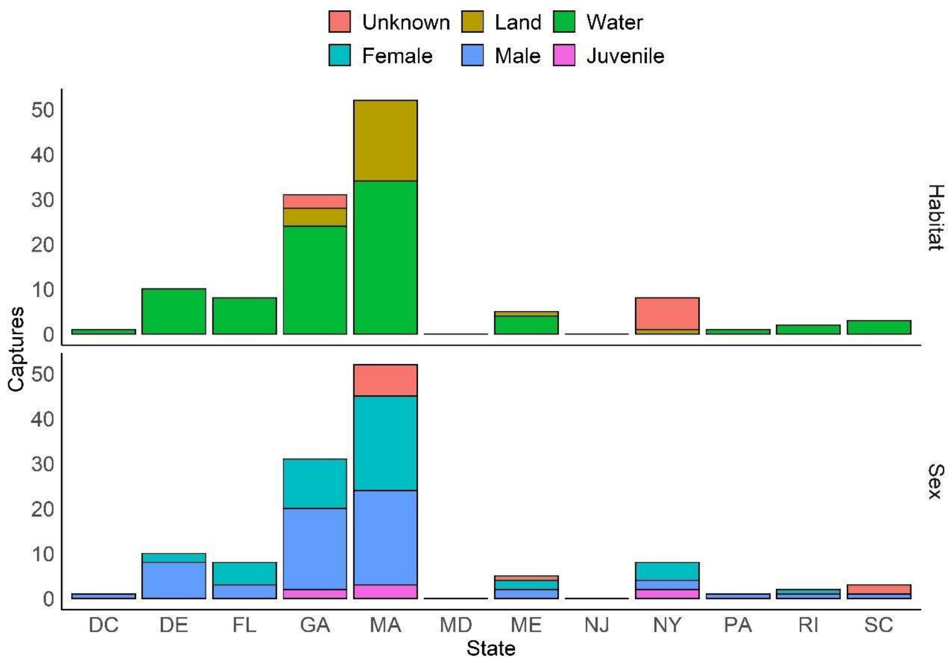


Figure 5-2. Number of Spotted Turtles captured during VRAs within each Sex/Age category and habitat category, by state. Source: VRA.

Trapping Assessments

Sites sampled using traps were either demographic assessment (DA) sites, high density (HD) DA sites, trap rapid assessment sites (TRAs), high density TRAs, or did not follow the regional protocol (NA; Table 5-2; Figure 5-3). In total, 7,536 traps were set as part of this sampling effort (Table 5-2; Figure 5-4), and there were 31,965 trap checks; 31,033 of these checks were of functional traps and/or traps that captured turtles (Table 5-2). Regionally, 2.9% of trap checks were of non-functional traps (e.g., low water level, hole in the trap, etc.) and 1.1% were of depredated traps (definition of depredation may have varied, e.g., bait stolen, trap pulled onto land, etc.). Trap checks were every 24 hours, with few exceptions. Maps at the end of this Chapter depict the number of sites trapped, traps set, trap checks, Spotted Turtle captures (by trap), catch per unit of effort (CPUE: captures/trap checks), and recapture rate (recaptures/total captures) for each state.

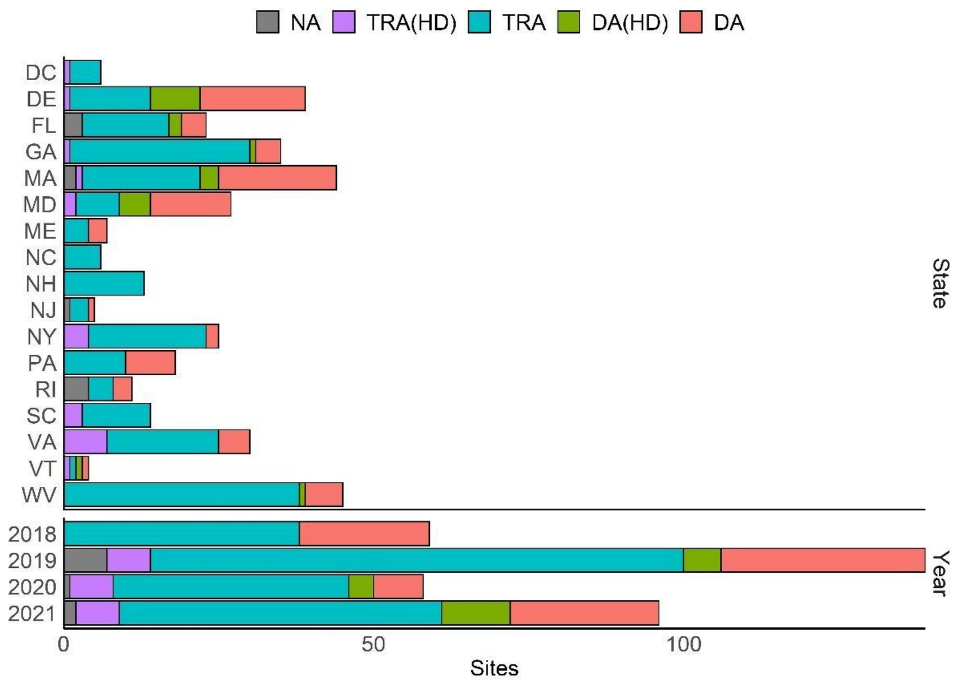


Figure 5-3. Count of sites sampled using each sampling framework within each state and year. Note that sites could be sampled using different frameworks if sampled more than once. Number of sites not available for Connecticut. Source: Trap set.

Table 5-2. The number of sites, traps, functional trap checks, Spotted Turtle captures, and catch per unit of effort (CPUE: captures/trap checks) within each state, year, and using the different trapping protocols. Totals provided are based on state totals (total sites can vary due to resampling of sites over time and using different protocols). Metrics could not be calculated for Connecticut. Source: Trap set/check.

Category		Sites	Traps	Checks	Captures	CPUE
State	DC	5	35	135	1	0.007
	DE	28	1,118	4,290	763	0.178
	FL	16	484	2,042	43	0.021
	GA	29	803	3,023	212	0.070
	MA	35	985	4,206	557	0.132
	MD	11	530	2,367	503	0.213
	ME	7	122	764	242	0.317
	NC	6	120	408	131	0.321
	NH	11	270	1,004	123	0.123
	NJ	4	125	498	63	0.127
	NY	22	503	1,995	179	0.090
	PA	18	388	2,327	136	0.058
	RI	10	218	799	51	0.064
	SC	13	245	932	3	0.003
	VA	26	987	3,855	534	0.139
	VT	2	77	306	18	0.059
	WV	42	526	2,082	182	0.087
Year	2018	59	1,816	7,356	819	0.111
	2019	127	2,943	13,029	1,568	0.120
	2020	51	1,038	4,165	498	0.120
	2021	80	1,739	6,483	856	0.132
Protocol	DA	77	3,175	14,535	2,191	0.151
	DA(HD)	20	697	2,915	373	0.128
	TRA	204	3,261	12,296	1,084	0.088
	TRA(HD)	21	346	1,133	67	0.059
	NA	10	57	154	26	0.169
Total		**285**	**7,536**	**31,033**	**3,741**	**0.121**

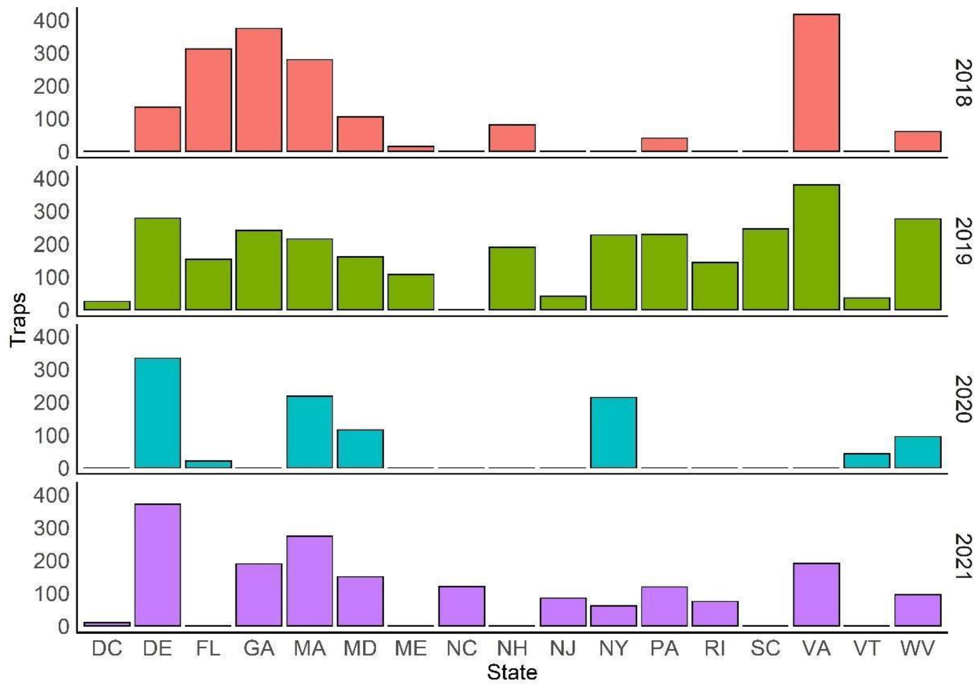


Figure 5-4. Number of traps set within each state and year. Number of traps not available for Connecticut. Source: Trap set.

Sampling Returns

Capture Method & Recapture Rate

In total, 3,399 Spotted Turtles were captured 4,698 times during the sampling period. The majority of captures were made by trap (84%, including non-protocol traps), although this varied by state (Figure 5-5).

The regional recapture rate (recaptures/total captures) was 0.277. To examine the difference in recapture rates between better-known and lesser-known sites, we split sampling sites into three categories: DA, TRA, and NA. If a site had ever been sampled using the DA sampling framework involving multiple trapping events, it was classified as "DA" and considered "better-known". If a site was never sampled using the DA framework, but was sampled using the TRA framework, it was classified as "TRA" and considered "lesser known". If a site was never sampled using either framework, it was classified as "NA". We then calculated the recapture rate for each site category, within each state (Table 5-3). All capture methods were included in these calculations.

The regional recapture rate at better-known sites (DA) was higher than at lesser-known sites (TRA). This pattern was consistent in most states that used multiple sampling frameworks. However, recapture rates in New York and Rhode Island were higher using the TRA framework (Table 5-3).

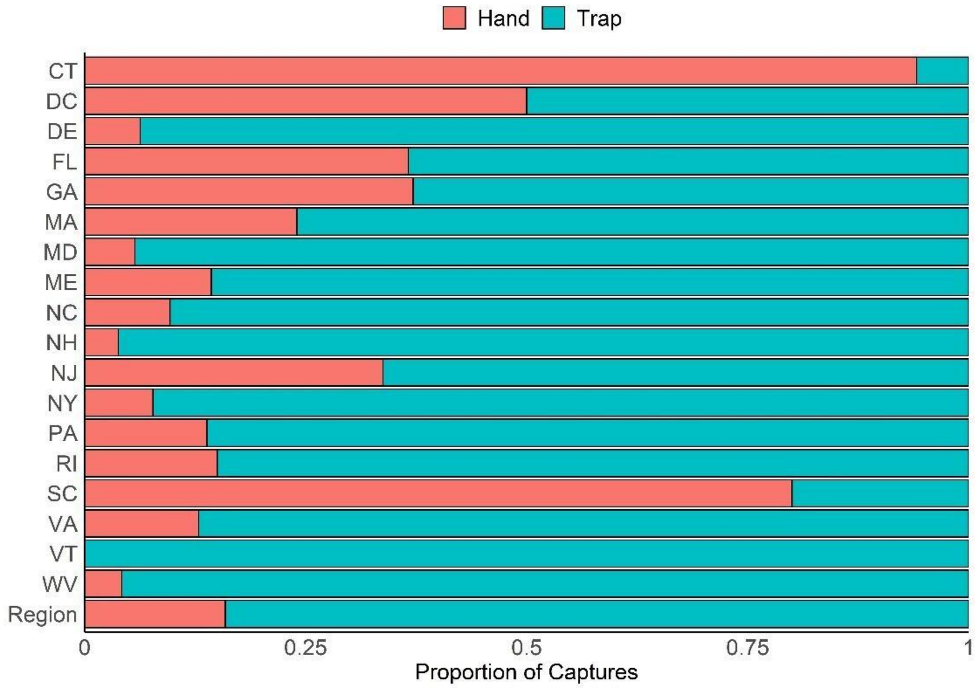


Figure 5-5. Proportion of total Spotted Turtle captures made by hand versus trap within each state. Source: Individual.

Table 5-3. Number of Spotted Turtle captures and individuals by site category (DA, TRA, NA) and state. Recapture rate was calculated dividing recaptures by the number of total captures. Source: Individual.

State	Captures				Individuals				Recapture rate		
	DA	NA	TRA	Total	DA	NA	TRA	Total	DA	NA	TRA
CT	0	51	0	51	0	43	0	43	0	0.157	0
DC	0	1	1	2	0	1	1	2	0	0	0
DE	787	0	25	812	557	0	21	578	0.292	0	0.16
FL	71	0	0	71	55	0	0	55	0.225	0	0
GA	313	0	26	339	95	0	20	115	0.696	0	0.231
MA	447	97	202	746	322	88	185	595	0.28	0.093	0.084
MD	541	3	0	544	356	3	0	359	0.342	0	0
ME	215	134	91	440	149	82	78	309	0.307	0.388	0.143
NC	0	0	145	145	0	0	133	133	0	0	0.083
NH	0	0	131	131	0	0	98	98	0	0	0.252
NJ	44	70	49	163	35	68	46	149	0.205	0.029	0.061
NY	95	8	91	194	79	7	72	158	0.168	0.125	0.209
PA	84	10	65	159	69	5	56	130	0.179	0.5	0.138
RI	14	7	39	60	13	7	34	54	0.071	0	0.128

SC	0	0	20	20	0	0	20	20	0	0	0
VA	351	0	262	613	214	0	221	435	0.39	0	0.156
VT	18	0	0	18	15	0	0	15	0.167	0	0
WV	190	0	0	190	151	0	0	151	0.205	0	0
Region	**3,170**	**381**	**1,147**	**4,698**	**2,110**	**304**	**985**	**3,399**	**0.334**	**0.202**	**0.141**

Sex Ratio

Observers recorded the sex of captured Spotted Turtles in the field. Across the eastern United States, males accounted for the majority of Spotted Turtle captures (Figure 5-6) and had the highest recapture rate (Table 5-4). However, the distribution of sexes varied by state with males comprising 39-64% of captures (Table 5-5; Figure 5-6). Additionally, the distribution of sexes varied by capture method, with males making up 58% of trap captures but only 45% of hand captures (Table 5-6).

Table 5-4. Number and percent of total Spotted Turtle captures and individuals by age and sex. Number of recaptures and recapture rate (recaptures/total captures) also provided. Source: Individual.

Category	Captures	% of total Captures	Individuals	% of total Individuals	Recaptures	Recapture Rate
Adult	4,172	88.80	2,946	86.67	1,226	0.294
Juvenile	372	7.92	331	9.74	41	0.110
Unk. age	154	3.28	122	3.59	32	0.208
Female	1,892	40.27	1,466	43.13	426	0.225
Male	2,617	55.70	1,765	51.93	852	0.326
Unk. sex	189	4.02	168	4.94	21	0.111

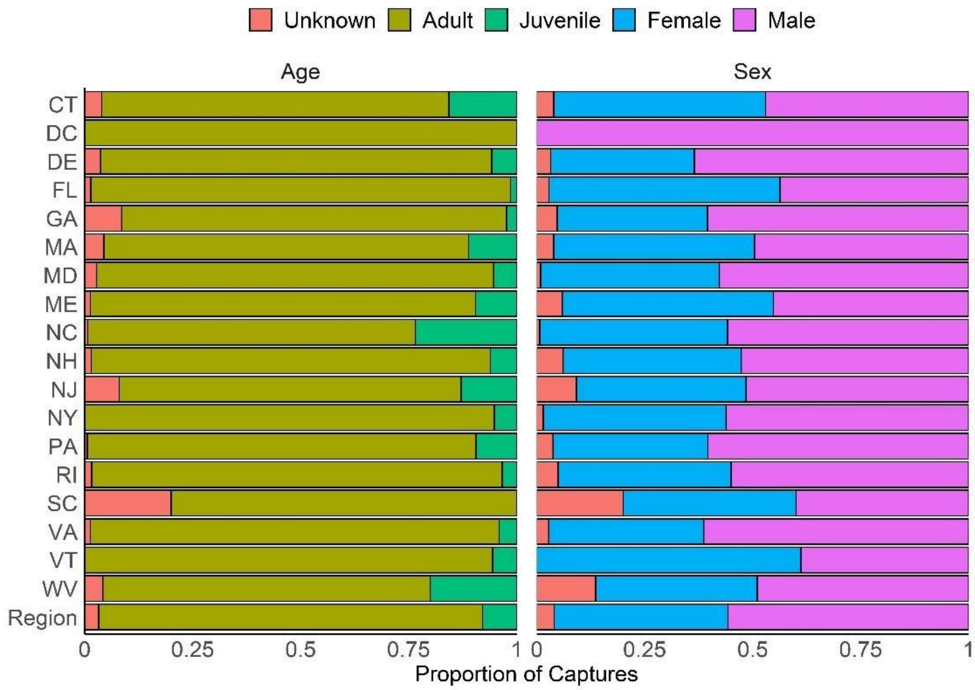


Figure 5-6. The proportion of total Spotted Turtle captures within each age and sex category by state and across the region. Source: Individual.

Table 5-5. Number of Spotted Turtle captures (caps) and individuals (inds) by age and sex category within each state and across the region. Source: Individual.

State	Total		Adult		Juvenile		Unk. Age		Female		Male		Unk. Sex	
	Caps	Inds	Caps	Inds	Caps	Inds	Caps	Inds	Caps	Inds	Caps	Inds	Caps	Inds
CT	51	43	41	34	8	8	2	1	25	22	24	19	2	2
DC	2	2	2	2	0	0	0	0	0	0	2	2	0	0
DE	812	578	735	513	47	43	30	22	270	215	516	341	26	22
FL	71	55	69	53	1	1	1	1	38	29	31	24	2	2
GA	339	115	302	94	8	1	29	20	118	50	205	52	16	13
MA	746	595	630	491	83	76	33	28	347	288	370	281	29	26
MD	544	359	500	326	29	25	15	8	225	172	314	184	5	3
ME	440	309	392	272	42	32	6	5	215	157	199	130	26	22
NC	145	133	110	99	34	33	1	1	63	60	81	72	1	1
NH	131	98	121	88	8	8	2	2	54	42	69	48	8	8
NJ	163	149	129	116	21	20	13	13	64	58	84	77	15	14
NY	194	158	184	149	10	9	0	0	82	73	109	83	3	2
PA	159	130	143	117	15	12	1	1	57	45	96	80	6	5
RI	60	54	57	51	2	2	1	1	24	23	33	28	3	3
SC	20	20	16	16	0	0	4	4	8	8	8	8	4	4
VA	613	435	580	403	25	24	8	8	220	162	376	258	17	15
VT	18	15	17	14	1	1	0	0	11	9	7	6	0	0
WV	190	151	144	108	38	36	8	7	71	53	93	72	26	26
Region	**4,698**	**3,399**	**4,172**	**2,946**	**372**	**331**	**154**	**122**	**1,892**	**1,466**	**2,617**	**1,765**	**189**	**168**

Table 5-6. Number and percent of total Spotted Turtle hand and trap captures by age and sex. Source: Individual.

	Hand		**Trap**	
	# Captures	**% Total hand captures**	**# Captures**	**% Total trap captures**
Adult	627	84%	3,545	90%
Juvenile	74	10%	298	8%
Unk. age	47	6%	107	3%
Female	344	46%	1,548	39%
Male	339	45%	2,278	58%
Unk. sex	65	9%	124	3%

To further investigate the distribution of captured male and female Spotted Turtles, we performed exact binomial tests in Program R (binom.test) to determine if the proportion of sexes varied significantly from expected (0.5). We used Bonferroni correction (p-value = 0.05/# total captures) to determine significance by state and capture method. We found that the proportion of male Spotted Turtle captures in the eastern United States was significantly larger than expected (Figure 5-7). This was also true for total trap captures and in four states: Delaware, Georgia, Maryland, and Virginia (Figure 5-7). Additionally, the proportion of male individuals in Delaware and Virginia was significantly larger than expected (Figure 5-7).

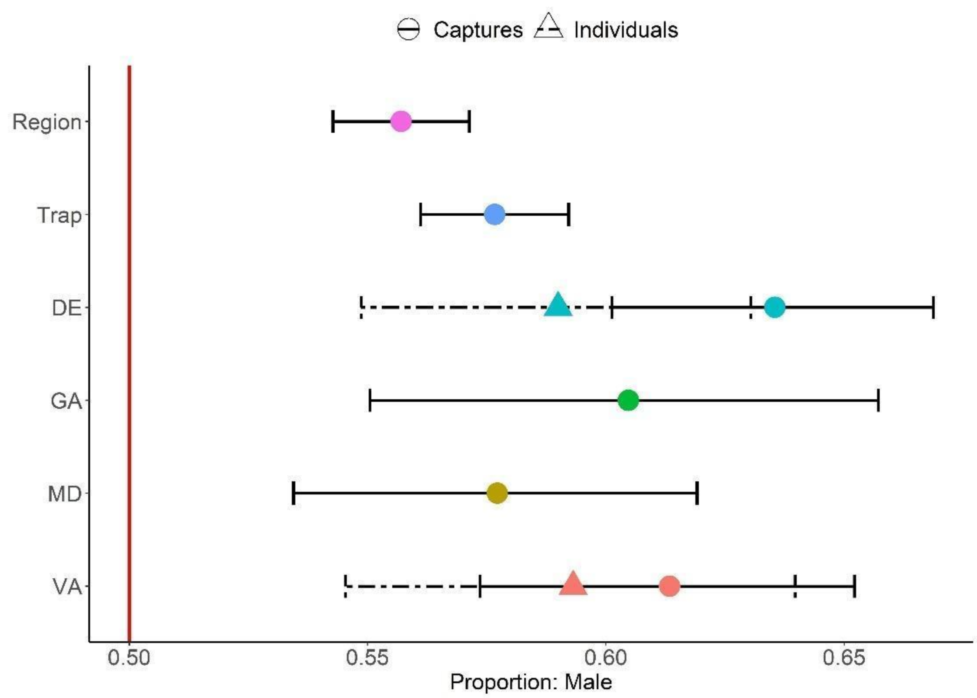


Figure 5-7. Based on 2018–2021 sampling, the estimated proportion of Spotted Turtle captures using traps that were of males in the eastern United States (Region) and within four states.

Estimated proportion of male individuals is also provided for Delaware and Virginia. Results are based on exact binomial tests; only significant results are reported. Source: individual.

Age Class

Three metrics were used to determine whether a Spotted Turtle was an adult or a juvenile for the following data summaries: plastron length, visible annuli, and how it was classified by an observer in the field. Size and age at sexual maturity vary throughout the Spotted Turtle range but for standardization, a single threshold was selected for each morphometric measurement.

We created density plots of plastron measurements (mm) and annuli counts for Spotted Turtles classified as juveniles and adults by observers in the field (Figure 5-8, 5-9). We then used the intersection point between juveniles and adults as thresholds for classification: 80 mm plastron length and eight visible annuli, which is consistent with previous estimates from the literature (Ernst 1970*a;* Ernst 1975; Ernst and Zug 1994*)*. Intersection points varied slightly when data was grouped by sub-region, but all were within 3 mm plastron length (New England: 83 mm, Mid-Atlantic: 78.5 mm, Southeast: 80 mm) and 1.5 annuli (New England: 8, Mid-Atlantic: 8.35, Southeast: 6.65), which we considered acceptable variation given the sample sizes (Southeast: 13 juveniles with measurements).

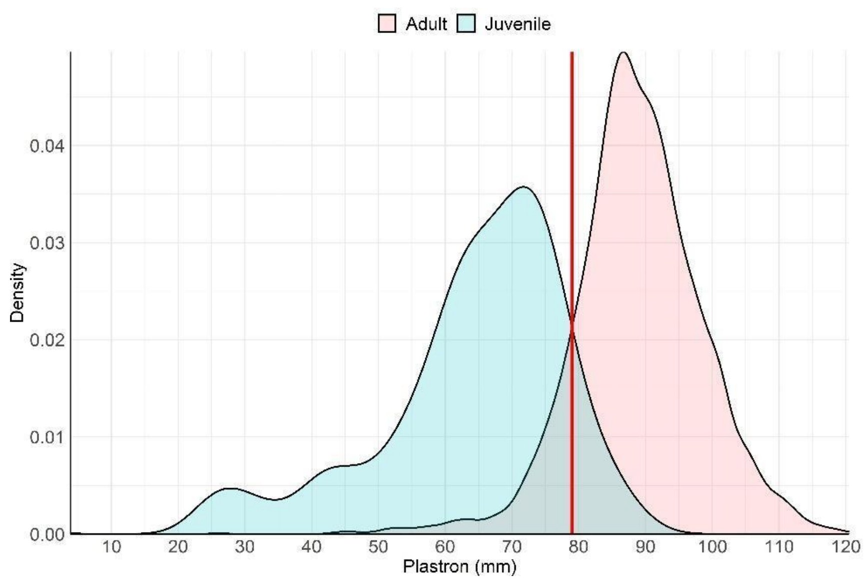


Figure 5-8. Density plot of plastron length (mm) for Spotted Turtles classified as juveniles and adults by observers in the field. The red line represents the threshold identified and used for classifying an individual's age (80 mm). Source: Individual.

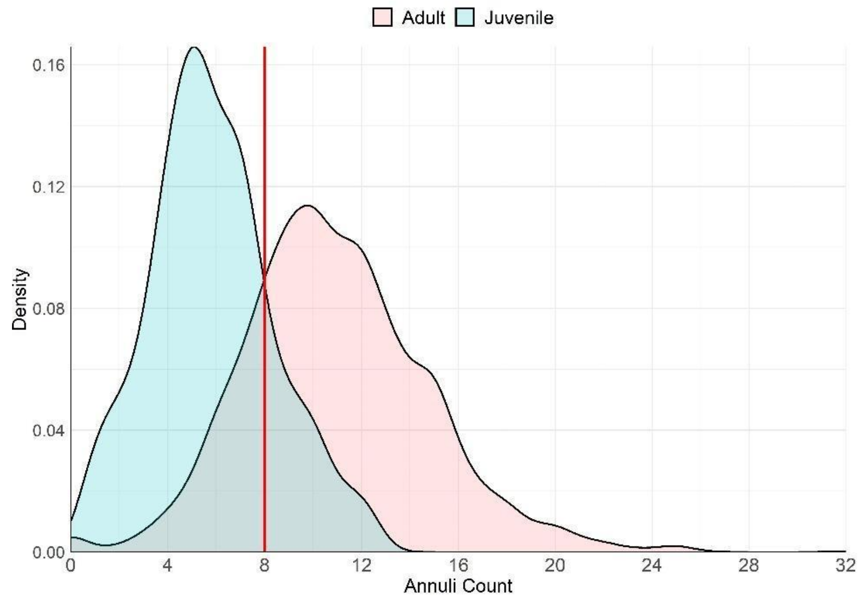


Figure 5-9. Density plot of visible annuli count for Spotted Turtles classified as juveniles and adults by observers in the field. The red line represents the threshold identified and used for classifying an individual's age (8 annuli). Source: Individual.

An individual turtle had to meet two out of three metric criteria based on morphometric measurements to be classified as either an adult or a juvenile. Metrics across all individual recaptures were considered when classifications were made. If a turtle did not meet these criteria (due to missing data), it was classified as unknown.

Adults accounted for 88.8% of all Spotted Turtle captures while juveniles accounted for 7.92% (Figure 5-6; Table 5-4). This distribution varied by state with juveniles comprising 0-23% of Spotted Turtle captures (Figure 5-6; Table 5-5). However, the distribution of adult and juvenile captures remained relatively stable for both hand and trap captures (Table 5-6). The recapture rate for adults was more than double that for juveniles (0.11; Table 5-4).

Catch Per Unit of Effort (CPUE)

CPUE: Turtle captures/functional trap checks

Sub-regions: New England (ME, NH, VT, MA, RI), northern (N.) Mid-Atlantic: (NY, PA, NJ), southern (S.) Mid-Atlantic (DE, DC, MD, WV, VA), Southeast (NC, SC, GA, FL).

Note(s):

- We were unable to calculate CPUE for Connecticut, so it has been excluded from the following summaries.
- Entries about traps and trap checks missing information about habitat and environmental variables of interest have been excluded from analysis.

- Some of the following summaries/analyses include subsets of data based on number of trap checks and captures, these should be indicated within the text and in Figure and Table captions.

During the four-year sampling period, 3,741 Spotted Turtle captures were made using traps (based on trap checks; Table 5-2). Catch per unit of effort (CPUE, captures/functioning trap checks) for the region was 0.12. However, CPUE varied from 0.06 in the Southeast to 0.16 in the S. Mid-Atlantic (and was 0.14 in New England and 0.08 in N. Mid-Atlantic). Regional CPUE using the DA sampling framework was 0.15, while the CPUE using the TRA sampling framework was 0.09 (Figure 5-10). CPUE using the DA sampling framework was higher in the majority of states that used both sampling protocols. However, CPUE was higher using the TRA sampling framework in Massachusetts, Pennsylvania, and Rhode Island (Figure 5-10). CPUE in Virginia was consistent using either sampling framework (Figure 5-10).

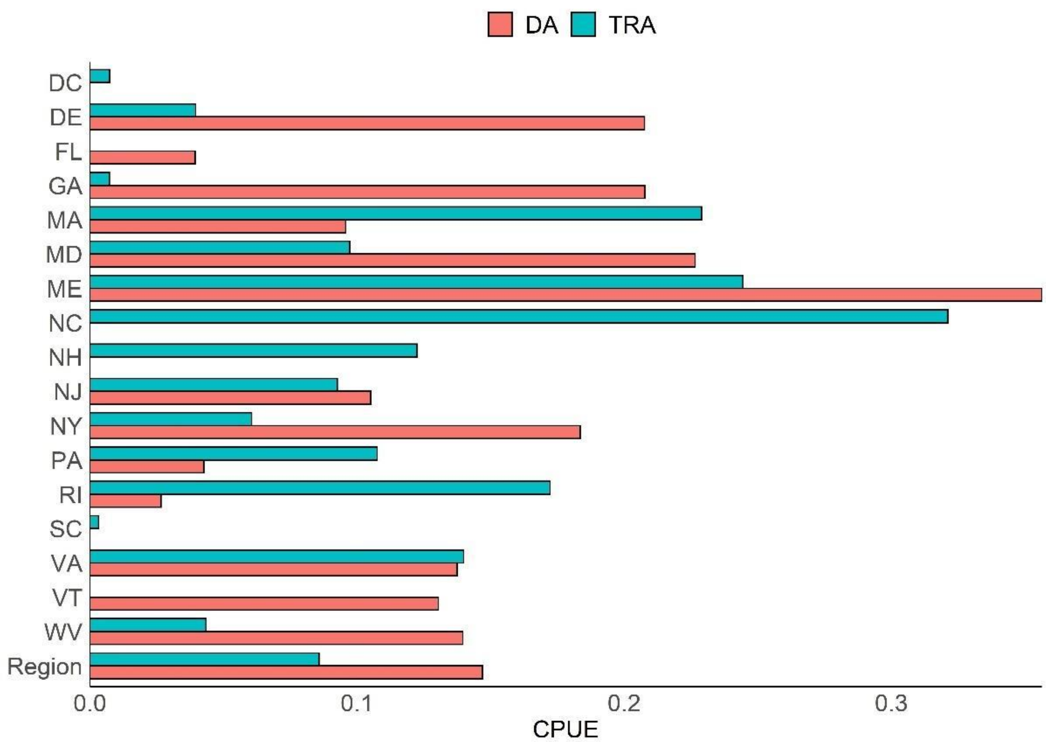


Figure 5-10. Catch per unit of effort (CPUE: captures/functioning trap checks) for TRA and DA sampling frameworks by state and across the region. Unable to calculate CPUE for Connecticut. Source: Trap check.

Habitat Type.—At the time of trap deployment, each trap location was classified by wetland type. These wetland types were then collapsed into nine major categories: beaver, ditch/pit, ecotone, emergent, forest, pond, river/creek, shrub, and vernal. Often, multiple wetland types could be used to classify the habitat in the sampling areas. Therefore, we allowed up to three habitat types to be assigned to a trap and summarized data for each wetland type separately (e.g., habitat classified as emergent/shrub: trap checks and turtle captures at this trap were used in both emergent and shrub summaries).

Using this collated and summarized trap habitat data, we calculated the regional CPUE for each habitat type (Table 5-7). CPUE was highest in vernal pools and lowest in river/creek wetland habitat (Table 5-7). However, this was not consistent across the eastern United States. We grouped states into four sub-regions: New England (ME, NH, VT, MA, RI), Northern Mid-Atlantic (NY, NJ, PA), Southern Mid-Atlantic (DE, MD, DC, WV, VA), and the Southeast (NC, SC, GA, FL); and calculated CPUE for each wetland type in each sub-region (Figure 5-11). CPUE was highest in shrub wetlands in the northern Mid-Atlantic sub-region, forested wetlands in New England, vernal pools in the southern Mid-Atlantic, and in ditches/pits in the Southeast (Figure 5-11).

Table 5-7. The number of traps, trap checks, Spotted Turtles captured, and catch per unit of effort (CPUE: captures/trap checks) within each wetland category. Source: Trap set/check.

Wetland type	Traps	Trap checks (functional)	Spotted Turtle captures	CPUE
Beaver	45	212	9	0.042
Ditch/Pit	1,053	4,189	639	0.153
Ecotone	242	1,163	74	0.064
Emergent	1,453	6,163	763	0.124
Forest	1,967	7,873	730	0.093
Pond	850	3,663	249	0.068
River/Creek	370	1,339	23	0.017
Shrub	752	3,021	416	0.138
Vernal	877	4,029	820	0.204

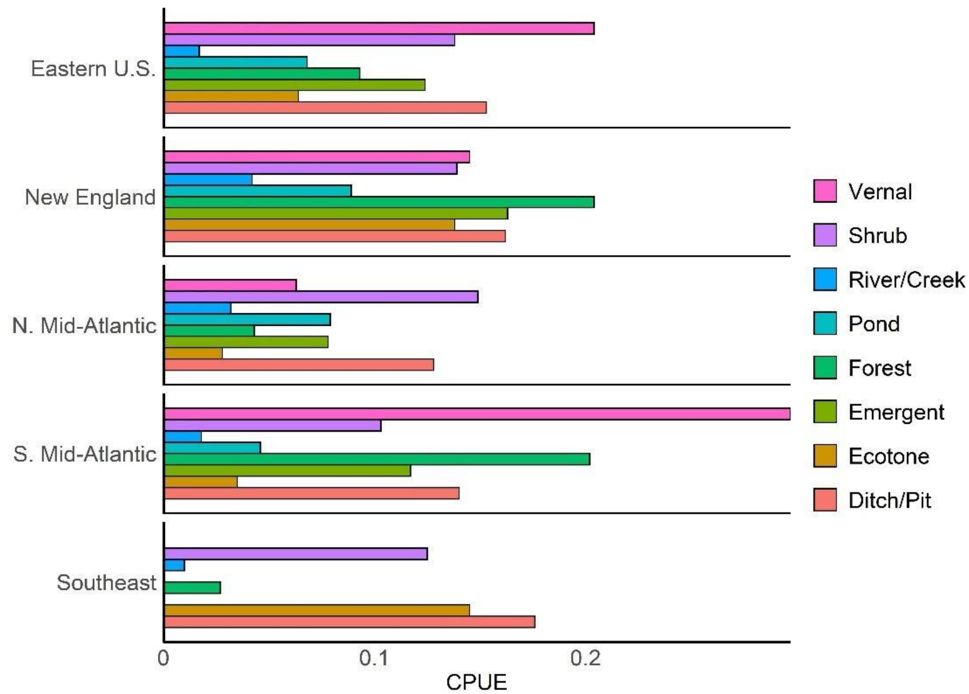


Figure 5-11. Catch per unit of effort (CPUE: Spotted turtle captures/trap checks) by habitat type and sub-region. Source: Trap set/check.

Percent Cover.—Observers listed the percent cover of canopy, shrub, emergent herbaceous, and submergent herbaceous vegetation within five meters of each trap set (Table 5-8). We binned percent cover, subset data by sub-region, and excluded any value range for a cover class that had less than 100 trap checks. We then calculated CPUE for each cover type across the eastern United States and by sub-region (Figure 5-12).

Table 5-8. Number of trap checks and Spotted Turtles captured within percent cover ranges of main vegetation cover categories assigned to trap set locations. Source: Trap set/check.

Percent cover	Canopy		Shrub		Emergent herbaceous		Submergent herbaceous	
	Checks	Turtles	Checks	Turtles	Checks	Turtles	Checks	Turtles
0%	7,342	768	7,641	748	8,170	1,059	15,446	1,904
0.5-9%	2,455	296	3,864	303	3,529	361	2,682	281
10-19%	2,700	322	4,657	524	3,028	325	2,890	265
20-29%	2,291	249	3,086	355	2,131	263	1,471	161
30-39%	1,683	156	2,126	280	1,705	216	934	131
40-49%	1,682	181	1,859	133	1,539	180	770	72
50-59%	1,823	174	1,845	304	1,883	227	716	67
60-69%	1,711	220	1,057	149	1,215	91	501	50
70-79%	2,085	306	1,004	185	1,720	161	653	86

80-89%	1,921	209	779	157	1,536	178	818	64
90-99%	2,049	306	569	136	1,848	226	1,057	135
100%	907	120	78	5	390	26	402	41

Next, we created linear and quadratic regressions between CPUE and percent cover for each vegetation category. We found no relationship between CPUE and percent cover in the Southeast but did identify a significant positive relationship between CPUE and shrub cover across the eastern United States ($F_{1,9}$=24.63, Adj. R^2=0.70, p=<0.001), in New England ($F_{1,9}$=12.34, Adj. R^2=0.53, p=<0.001), and in the northern Mid-Atlantic ($F_{1,8}$=9.04, Adj. R^2=0.47, p=0.017). There was also a significant positive linear relationship between CPUE and emergent herbaceous cover in the northern Mid-Atlantic ($F_{1,10}$=10.54, Adj. R^2=0.46, p=0.009); interestingly, the inverse of this relationship was nearly significant in the southern Mid-Atlantic ($F_{1,10}$=4.73, Adj. R^2=0.25, p=0.055). However, there was a significant positive linear relationship between CPUE and canopy cover in the southern Mid-Atlantic ($F_{1,10}$=17.72, Adj. R^2=0.30, p=0.002). Quadratic regressions were also significant for all of the reported relationships above. However, linear regressions appeared to better suit the patterns observed in the data. The binning of percent classes may mask some relationships but was necessary to get sufficient sample sizes to test for relationships between CPUE and percent cover within sub-regions.

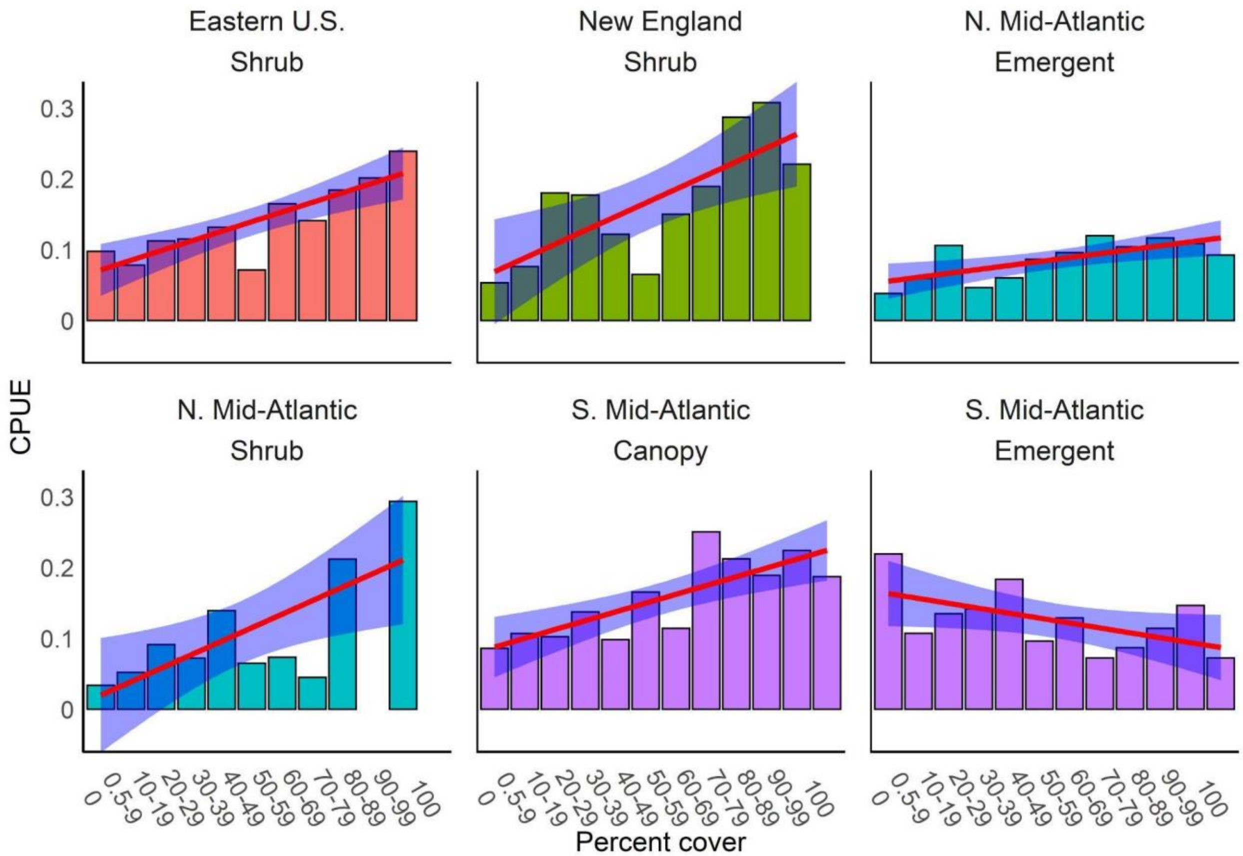


Figure 5-12. Catch per unit of effort (CPUE: Spotted Turtle captures/trap working checks) for percent cover intervals of shrub, canopy, and emergent herbaceous vegetation within 5 m of traps in different sub-regions. Only significant linear relationships are shown, linear regressions are shown in red and shaded areas indicate 95% confidence intervals. CPUE for percent cover ranges with fewer than 100 trap checks are not shown. Source: Trap set/check.

Water Depth and Distance Upland.—At the time of trap deployment, water depth at the trap and distance to upland from the trap were recorded in meters. The majority (61%) of traps were set at water depths between 0.2 and 0.4 meters and the highest CPUE across the eastern United States was at 0.5–0.6 meters (Table 5-9). However, this varied by sub-region. CPUE was highest at 1.0–1.1 m in New England, 0.1–0.2 m in the northern Mid-Atlantic, 0.3–0.4 in the southern Mid-Atlantic, and at 0.5–0.6 in the Southeast (Figure 5-13). We did not calculate CPUE for depths with fewer than 100 trap checks.

Table 5-9. Number of traps set, trap checks, Spotted Turtle captures, and catch per unit of effort (CPUE: Spotted Turtle captures/trap working checks) at different water depths across the eastern United States. Source: Trap set/check.

Depth (m)	Traps	Trap checks (functioning)	Spotted Turtle captures	CPUE
0.1-0.2	495	1,961	180	0.092
0.2-0.3	1,884	7,964	848	0.106
0.3-0.4	2,217	8,948	1,117	0.125
0.4-0.5	567	2,264	186	0.082
0.5-0.6	868	3,705	582	0.157
0.6-0.7	126	586	20	0.034
0.7-0.8	71	284	17	0.060
0.8-0.9	160	705	60	0.085
0.9-1.0	25	106	1	0.009
1.0-1.1	295	1,376	159	0.116
>1.1	59	429	25	0.058

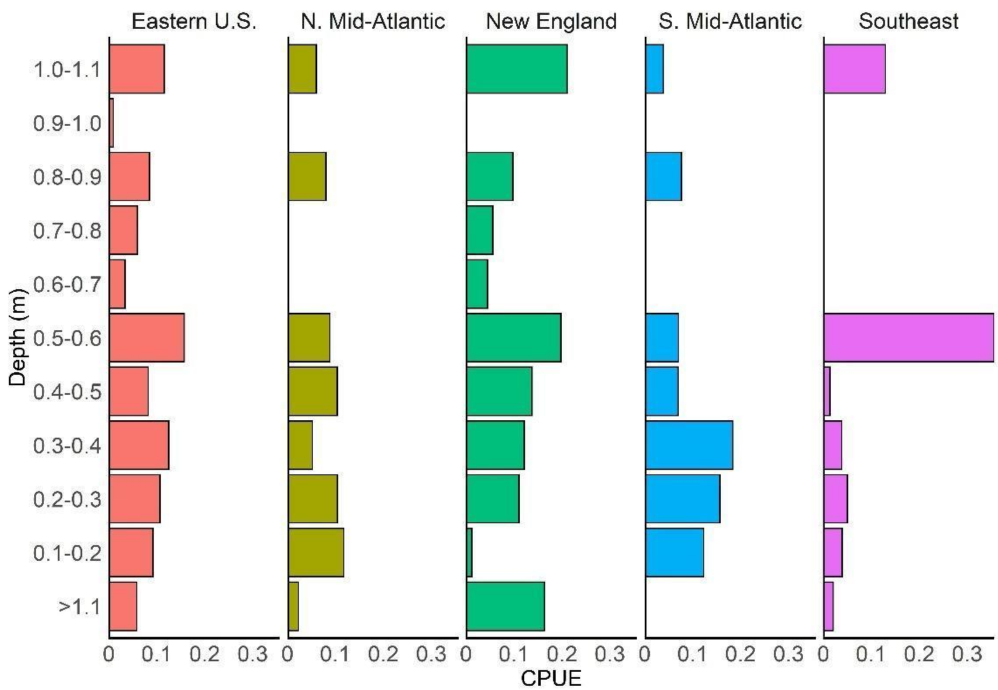


Figure 5-13. Catch per unit of effort (CPUE: Spotted Turtle captures/working trap checks) at different intervals of water depth in different sub-regions. CPUE for water depths with fewer than 100 trap checks are not shown. Source: Trap set/check.

Almost half of all the traps set were placed within 5 m of upland habitat (47%; Table 5-10). The majority of turtles were also caught within 5 m of upland habitat, but CPUE was highest at 25–50 m upland (Table 5-10). However, CPUE in the eastern United States was generally stable across all distances from upland (Table 5-10; Figure 5-14). CPUE was more variable across distances from upland in different sub-regions (Figure 5-14), but the plurality of turtles was always captured at 0–5 m.

Table 5-10. Number of traps set at different distances upland and their trap checks, Spotted Turtle captures, and catch per unit of effort (CPUE: Spotted Turtle captures/trap working checks). Source: Trap set/check.

Dist. upland (m)	Traps	Trap checks (functioning)	Spotted Turtle captures	CPUE
0-5	3,162	12,881	1,577	0.122
5-10	1,225	5,130	594	0.116
10-15	661	2,842	318	0.112
15-20	328	1,375	162	0.118
20-25	284	1,238	116	0.094
25-50	512	2,110	266	0.126
50-75	267	1,125	132	0.117
>75	224	1,017	93	0.091

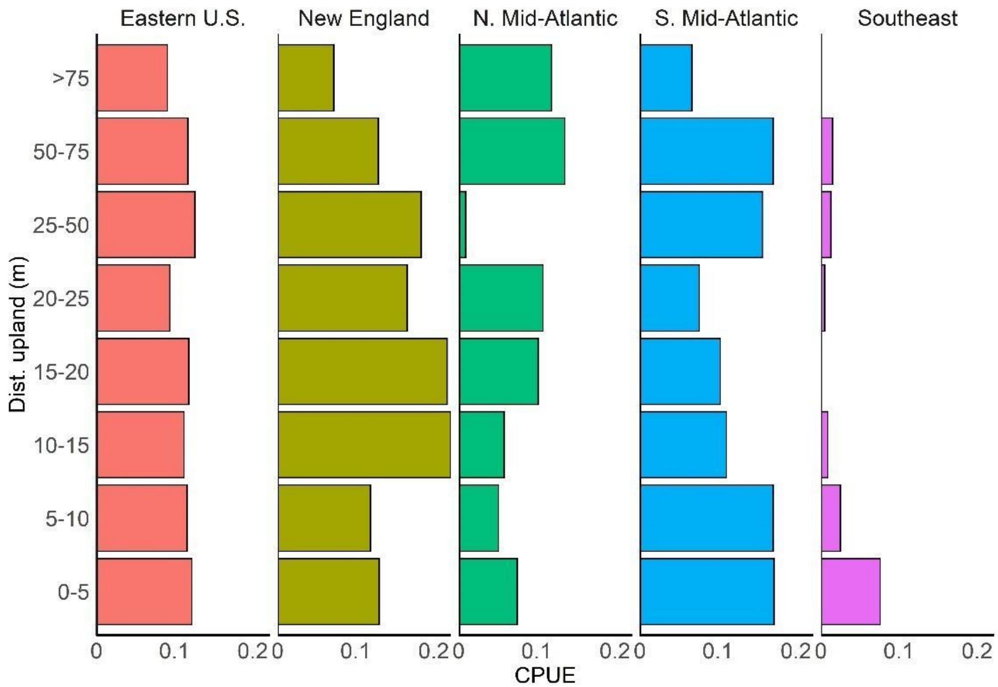


Figure 5-14. Catch per unit of effort (CPUE: Spotted Turtle captures/working trap checks) with different distances to upland in different sub-regions. CPUE for distances to upland with fewer than 100 trap checks are not shown. Source: Trap set/check.

Seasonality .—Across the region, traps were set from February (2/19) through November (11/11), with peak effort occurring in late April through mid-May (Figure 5-15). We calculated CPUE by day of year for all sub-regions and tested whether there were linear and/or quadratic relationships between trap returns and day of year.

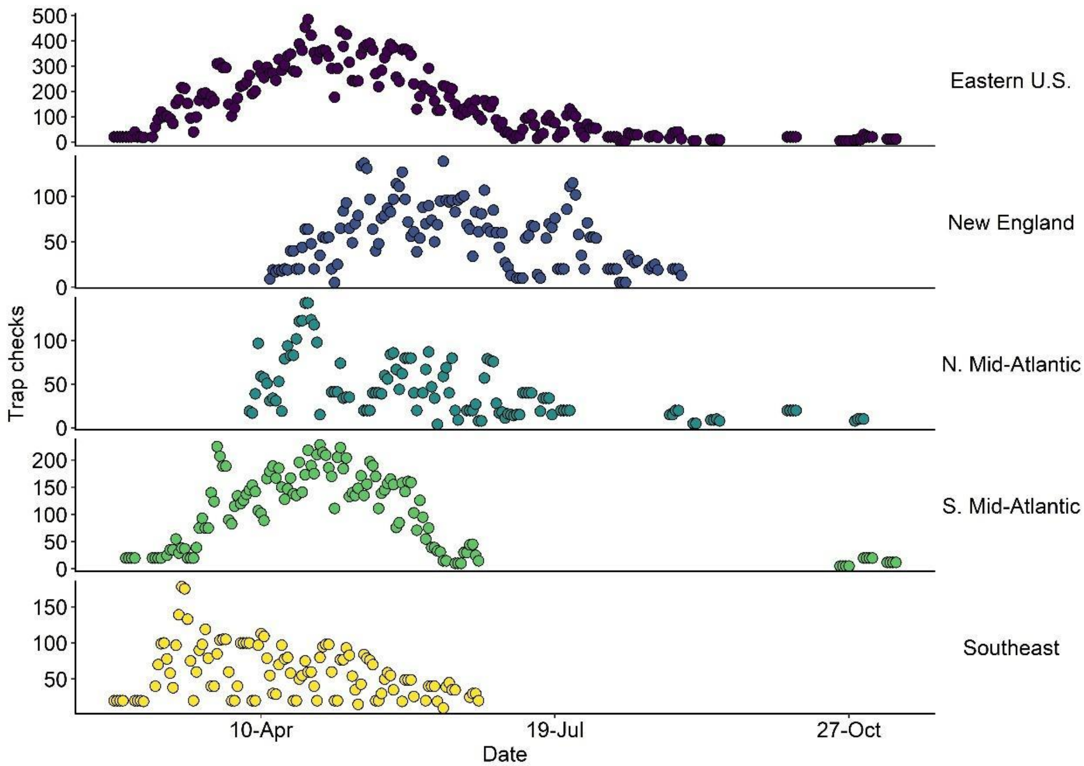


Figure 5-15. Number of trap checks by date within each sub-region, pooled across years. Source: Trap checks.

CPUE had weak but significant linear and quadratic relationships with day of year across the eastern United States, in both the northern and southern Mid-Atlantic, and in the Southeast (Figure 5-16). However, a quadratic relationship better described patterns in the data across the eastern United States ($F_{2,205}$=13.48, Adj. R^2=0.11, p=<0.001) and in the southern Mid-Atlantic ($F_{2,122}$=14.95, Adj. R^2=0.18, p=<0.001). Conversely, a negative linear relationship better described the patterns in the data from the northern Mid-Atlantic ($F_{1,111}$=12.92, Adj. R^2=0.10, p=<0.001) and the Southeast ($F_{1,107}$=16.24, Adj. R^2=0.12, p=<0.001). When the data was subset to only include days with at least 100 trap checks the only significant relationship between CPUE and date was a quadratic relationship in the northern Mid-Atlantic ($F_{2,33}$=4.31, Adj. R^2=0.16, p=0.02). However, this was based on a small sample size and therefore more unreliable.

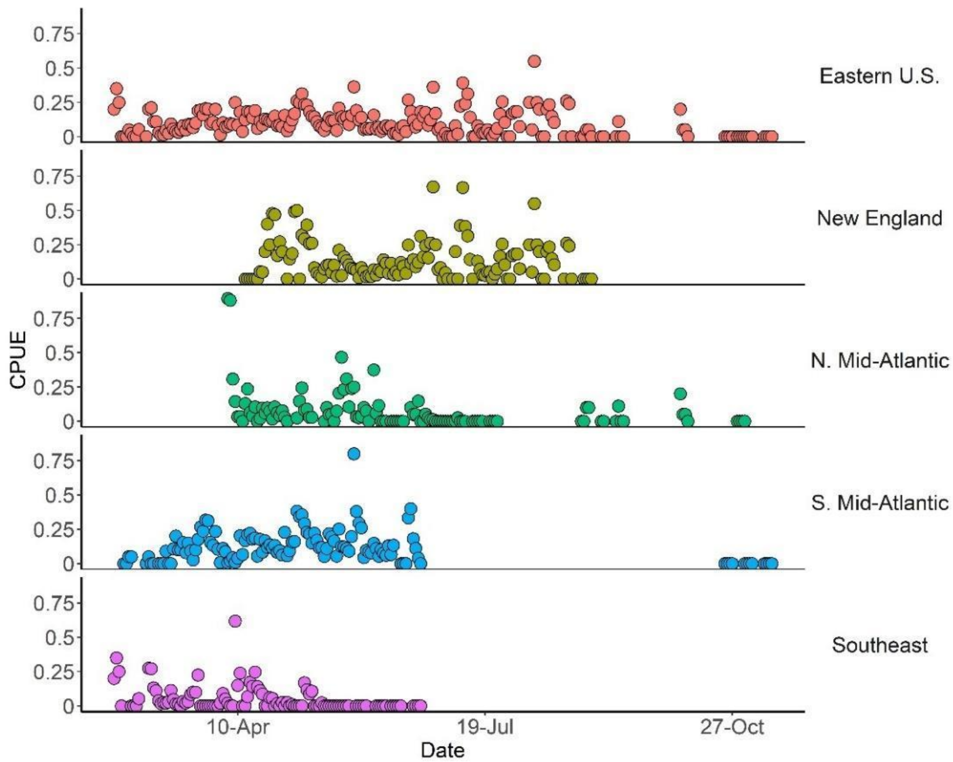


Figure 5-16. Catch per unit of effort (CPUE: captures/trap checks) by date across the eastern United States, and by sub-region. Source: Trap checks.

We also examined the relationship between CPUE, day of year, and the age and sex of Spotted Turtles captured in traps (Figure 5-17). We could not assess these patterns across sub-regions in the eastern United States due to data scarcity. Additionally, we subset the data to include only dates where there were at least 100 trap checks across the eastern United States, to eliminate outliers based on low sample size.

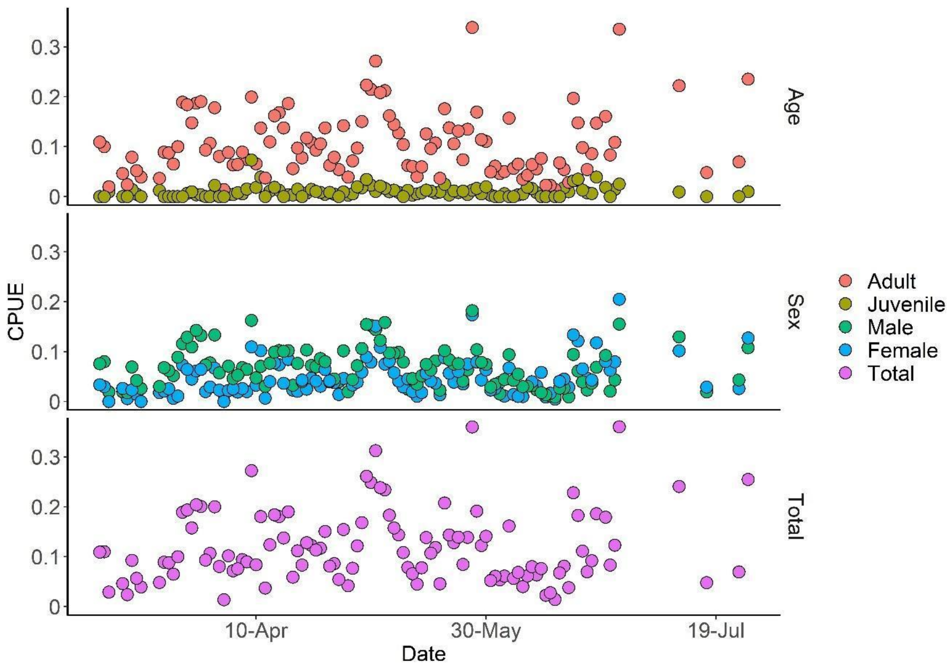


Figure 5-17. Catch per unit of effort (CPUE: captures/trap checks) by date for adult, juvenile, male, female, and all turtles captured. Data was subset to dates with at least 100 trap checks. Source: Individual/Trap check.

Only female Spotted Turtle captures had a significant, albeit weak, relationship with day of year. Both a linear and a quadratic regression fit the data, but a positive linear regression appeared to better explain the pattern in the data ($F_{1,110}$=12.93, Adj. R^2=0.10, p=<0.001; Figure 5-18).

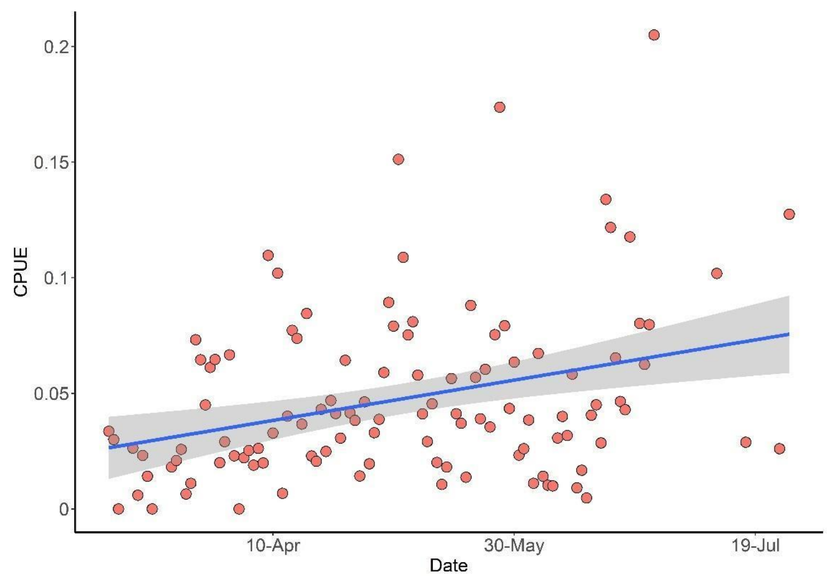


Figure 5-18. Catch per unit of effort (CPUE: captures/trap checks) by day of year for female Spotted Turtle captures in traps across the eastern United States. Only dates with at least 100 trap checks are shown, a linear regression is displayed in blue with its 95% confidence interval in gray. Source: Individual/Trap check.

Temperature.—Air and water temperature was recorded by observers when they checked traps (Table 5-11). We used this information to examine the relationship between trap returns and temperature across the eastern United States and within sub-regions (Figure 5-19). CPUE across the eastern United States peaked around 15–25 degrees Celsius (Table 5-11; Figure 5-19).

Table 5-11. Air and water temperature ranges in Celsius and their associated number of trap checks, Spotted Turtle captures, and catch per unit of effort (CPUE: captures/trap checks). Source: Trap checks.

Temperature Range (C)	Air			Water		
	Captures	Checks	CPUE	Captures	Checks	CPUE
0-5	13	168	0.077	2	44	0.045
5-10	167	1,764	0.095	116	1,645	0.071
10-15	608	4,667	0.130	705	6,586	0.107
15-20	825	6,477	0.127	1,350	10,333	0.131
20-25	1,154	8,393	0.137	717	6,285	0.114
25-30	474	4,795	0.099	96	1,122	0.086
>30	71	1,291	0.055	1	57	0.018

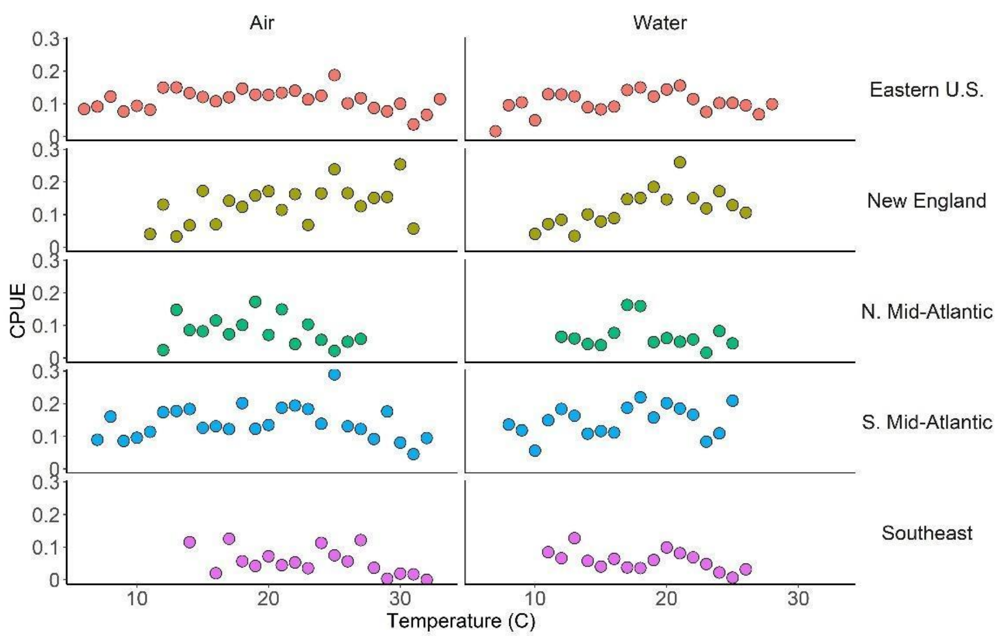


Figure 5-19. Catch per unit of effort (CPUE: captures/trap checks) by air and water temperatures with at least 100 trap checks across the eastern United States and by sub-region. Source: Trap check.

To reduce the influence of outliers, temperatures with fewer than 100 trap checks were excluded when we fit linear and quadratic regressions to the data. We found that there was a significant quadratic relationship between CPUE across the eastern United States and water ($F_{2,19}$=6.36, Adj.

R^2=0.34, p=0.008) and air temperature ($F_{2,25}$=7.89, Adj. R^2=0.34, p=0.002; Figure 5-20). Both linear and quadratic regressions fit CPUE and water and air temperature in New England, but the quadratic regression appeared to better explain the pattern between CPUE and water ($F_{2,14}$=9.71, Adj. R^2=0.52, p=0.002; Figure 5-20) and air temperature ($F_{2,18}$=3.63, Adj. R^2=0.34, p=0.047; Figure 5-20). There was also a significant quadratic relationship between CPUE in the southern Mid-Atlantic and air temperature ($F_{2,23}$=4.87, Adj. R^2=0.24, p=0.017; Figure 5-20). Finally, a negative linear relationship best explained the relationship between CPUE in the Southeast and water ($F_{1,14}$=5.51, Adj. R^2=0.23, p=0.034; Figure 5-21) and air temperature ($F_{1,16}$=4.84, Adj. R^2=0.18, p=0.043; Figure 5-21).

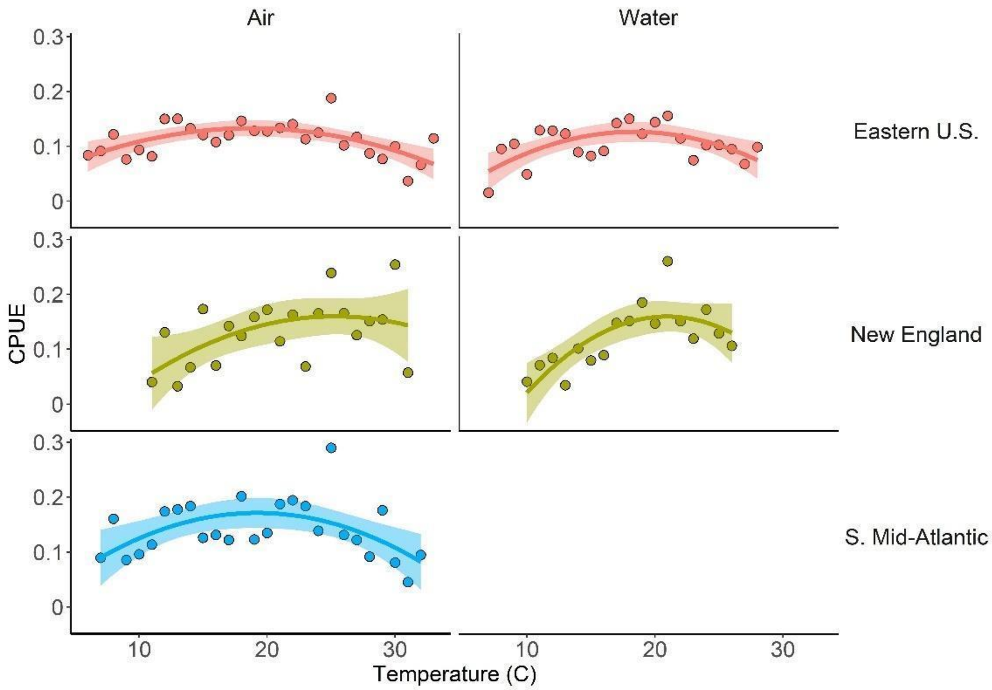


Figure 5-20. Catch per unit of effort (CPUE: captures/trap checks) by air and water temperatures with more than 100 trap checks in the eastern United States, New England, and the southern Mid-Atlantic. Quadratic regressions are fit to the data and 95% confidence intervals are shown. Source: Trap check.

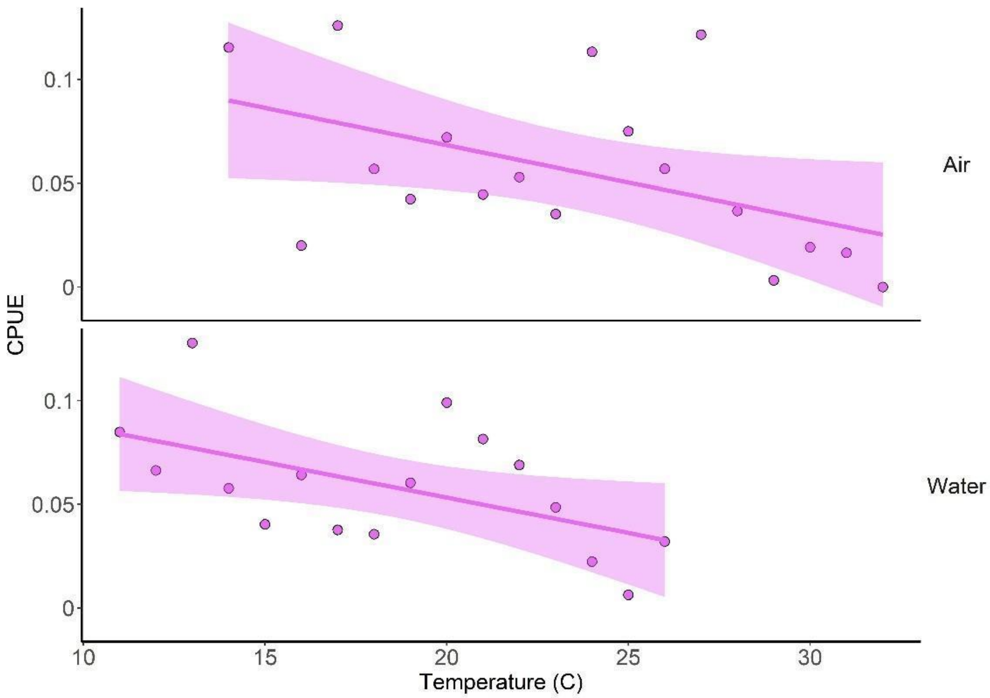


Figure 5-21. Catch per unit of effort (CPUE: captures/trap checks) by air and water temperatures with more than 100 trap checks in the Southeast. Linear regressions are fit to the data and 95% confidence intervals are shown. Source: Trap check.

We also examined the influence of air and water temperature on the CPUE of Spotted Turtles based on their age and sex (Figure 5-22). Again, we eliminated any temperature with fewer than 100 trap checks. There was a significant quadratic relationship between air temperature and the CPUE of females ($F_{2,25}$=8.87, Adj. R^2=0.37, p=0.001; Figure 5-23), males ($F_{2,25}$=7.8, Adj. R^2=0.34, p=0.002; Figure 5-23), and all adults ($F_{2,25}$=9.7, Adj. R^2=0.39, p=<0.001; Figure 5-23). There was also a significant quadratic relationship between water temperature and the CPUE of males ($F_{2,19}$=3.53, Adj. R^2=0.19, p=0.05; Figure 5-23), adults ($F_{2,19}$=5.97, Adj. R^2=0.32, p=0.01; Figure 5-23), and juveniles ($F_{2,19}$=10.34, Adj. R^2=0.47, p=<0.001; Figure 5-23). Both a linear and quadratic model fit the female CPUE and water temperature data; however, a quadratic relationship appeared to better explain the pattern in the data ($F_{2,19}$=12.37, Adj. R^2=0.52, p=<0.001; Figure 5-23).

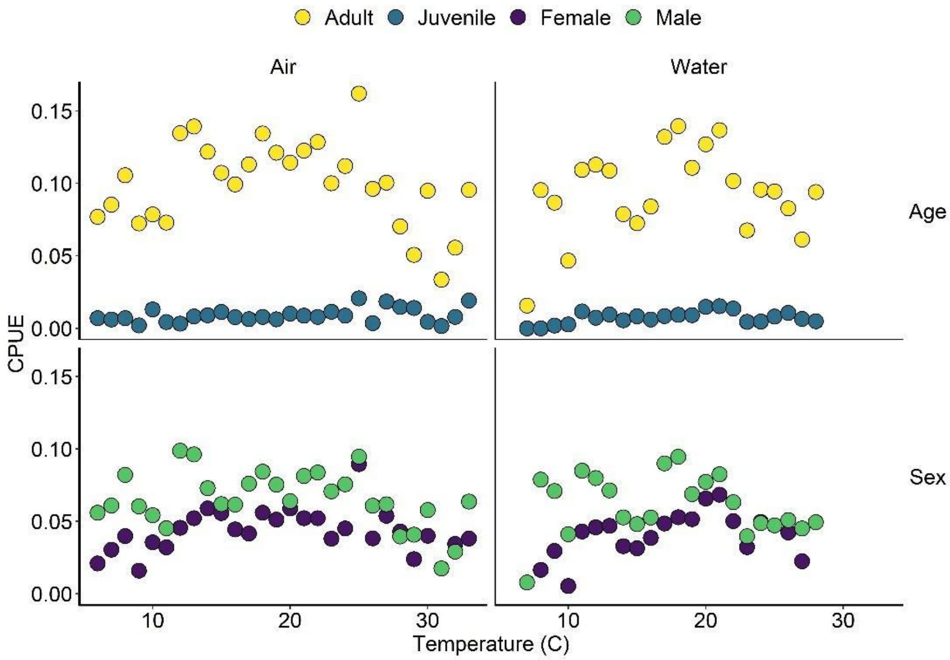


Figure 5-22. Catch per unit of effort (CPUE: captures/trap checks) by air and water temperature for female, male, adult, and juvenile Spotted Turtles. Temperatures with fewer than 100 trap checks excluded. Source: Individual/Trap check.

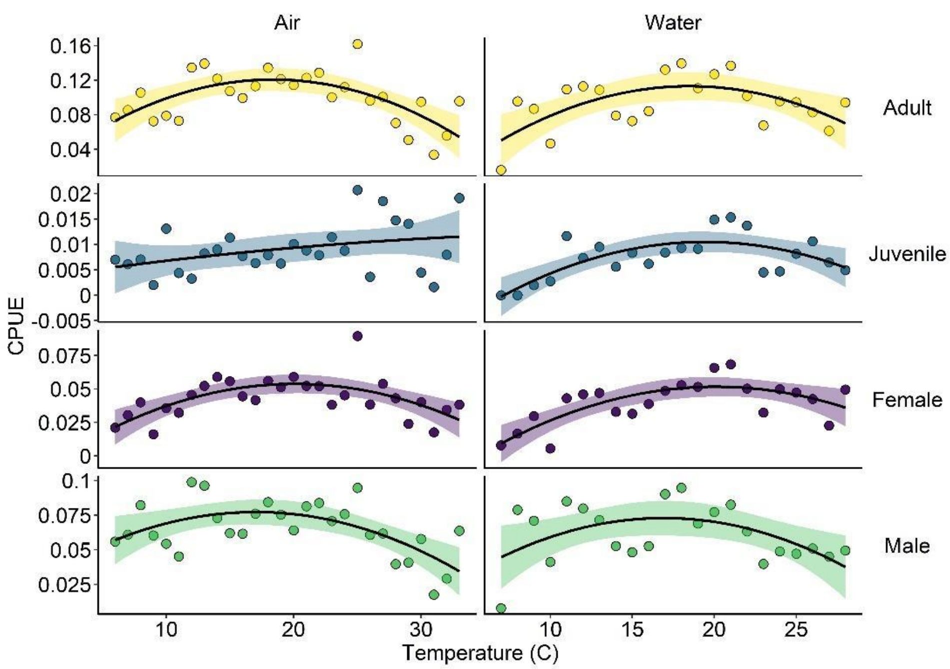


Figure 5-23. Catch per unit of effort (CPUE: captures/trap checks) by air and water temperature for female, male, adult, and juvenile Spotted Turtles. Temperatures with fewer than 100 trap checks excluded. Quadratic regressions are fit to the data and 95% confidence intervals are shown. Source: Individual/Trap check.

Capture Success Over Time Within a Sampling Event .—Both TRA and DA sampling frameworks utilized trap events of 4 nights. In the DA sampling framework, these events could be consecutive for a total of 12 trapping nights. However, 91% of total trap checks and 86–97% of sub-regional trap checks were within the one to four trap night range. Therefore, we focused on the change in trap success over one to four trap nights (Table 5-12).

Table 5-12. The number of trap checks and Spotted Turtle captures by trap night and sub-region. Source: Trap check.

Trap night	Metric	Eastern U.S.	New England	N. Mid-Atlantic	S. Mid-Atlantic	Southeast
1	Checks	7,368	1,623	998	3,133	1,614
	Captures	1,180	299	142	575	164
2	Checks	7,268	1,587	978	3,100	1,603
	Captures	884	218	82	478	106
3	Checks	7,048	1,545	903	3,053	1,547
	Captures	775	202	73	425	75
4	Checks	6,563	1,417	884	2,790	1,472
	Captures	621	125	43	410	43

We calculated the CPUE for trap nights one through four for every site sampled and pooled these by sub-region to assess relationships across the eastern United States. CPUE appeared to decrease by trap night and this relationship was most pronounced in New England and across the eastern United States (Figure 5-24).

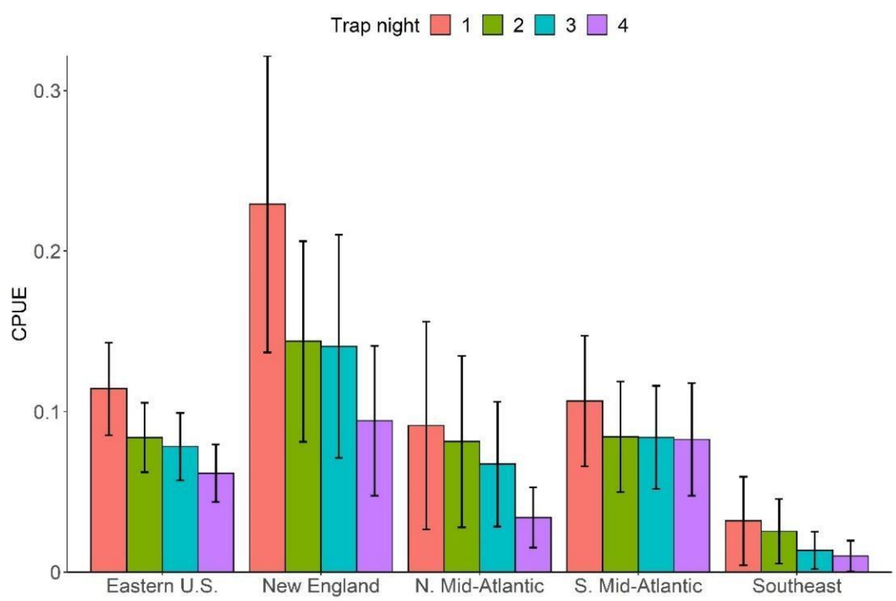


Figure 5-24. Catch per unit of effort (CPUE: captures/trap checks) and 95% confidence intervals by sub-region and trap night. Source: Trap check.

We fit linear regressions to CPUE by trap night (Figure 5-25) and found significant negative relationships in the eastern United States ($F_{1,1034}$=9.92, Adj. R^2=0.01, p=0.002; Figure 5-25) and in New England ($F_{1,218}$=6.92, Adj. R^2=0.03, p=0.009; Figure 5-25). However, these relationships were weak and explained little variance in the data.

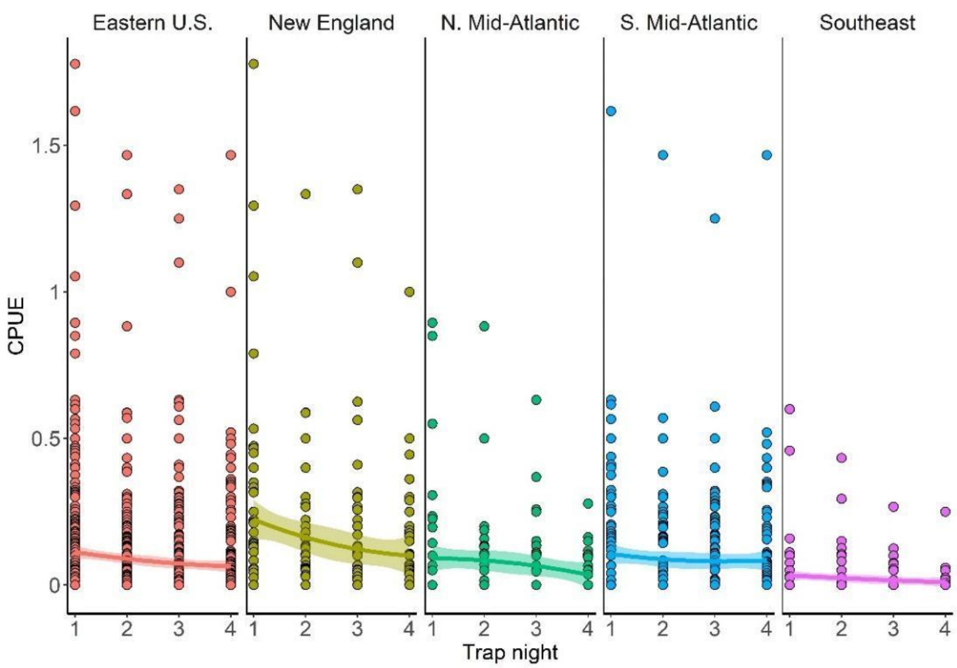


Figure 5-25. Catch per unit of effort (CPUE: captures/trap checks) by sub-region and trap night. Linear regressions and their 95% confidence intervals are also displayed. Source: Trap check.

Other Turtle Species Observed

In addition to Spotted Turtles, 12 other turtle species were captured in traps during the sampling period. The most common species was the Painted Turtle (*Chrysemys picta*; Table 5-13) and the least common species were the Florida Softshell Turtle (*Apalone ferox*, n = 3) and Eastern Box Turtle (*Terrapene c. carolina*, n = 1). Only Painted and Snapping Turtles (*Chelydra serpentina*) were captured in all sampled states. Painted Turtles had the highest CPUE across the eastern United States, in New England, and northern and southern Mid-Atlantic (Table 5-13). However, the Eastern Mud Turtle (*Kinosternon subrubrum*) had the highest CPUE in the Southeast (Table 5-13).

Table 5-13. Number (#) and catch per unit of effort (CPUE: captures/trap checks) for other turtle species captured in Spotted Turtle sampling traps, by sub-region. Source: Trap check.

Turtle Species	**Eastern U.S.**		**New England**		**N. Mid-Atlantic**		**S. Mid-Atlantic**		**Southeast**	
	#	**CPUE**	**#**	**CPUE**	**#**	**CPUE**	**#**	**CPUE**	**#**	**CPUE**
Painted	7,341	0.237	2,670	0.377	1,572	0.326	2,964	0.233	135	0.021
Snapping	670	0.022	142	0.02	172	0.036	312	0.025	44	0.007
Eastern Mud	2,294	0.074	93	0.013	72	0.015	1,581	0.124	548	0.086

Striped Mud	335	0.011	1	0	1	0	55	0.004	278	0.043
Common Musk	376	0.012	2	0	33	0.007	118	0.009	223	0.035
Loggerhead Musk	31	0.001	1	0	0	0	0	0	30	0.005
Blanding's	169	0.005	169	0.024	0	0	0	0	0	0
Wood	18	0.001	1	0	7	0.001	10	0.001	0	0
Slider	146	0.005	2	0	1	0	52	0.004	91	0.014
Northern Red-bellied	14	0	0	0	0	0	8	0.001	6	0.001

Seasonality.—To examine the relationship between CPUE of other turtle species and day of year and habitat characteristics, we subset the data to only include species with over 100 captures that were captured in all 4 sub-regions. This left Painted, Snapping, Eastern Mud, Striped Mud (*Kinosternon baurii*), Common Musk Turtles (*Sternotherus odoratus*), and Sliders (*Trachemys scripta*). To look at CPUE by seasonality, we further subset the data to days with at least 100 trap checks (Figure 5-26).

We found significant linear and quadratic relationships between day of year and CPUE of the most-detected species: Painted, Snapping, and Eastern Mud Turtles (Figures 5-26, 5-27). However, positive linear relationships appeared to better fit the pattern in the data for Painted ($F_{1,112}$=42.84, Adj. R^2=0.27, p=<0.001; Figure 5-27) and Snapping Turtles ($F_{1,112}$=60.62, Adj. R^2=0.35, p=<0.001; Figure 5-27). Conversely, a quadratic regression appeared to better describe the pattern in Eastern Mud Turtle CPUE ($F_{2,111}$=29.06, Adj. R^2=0.33, p=<0.001; Figure 5-27).

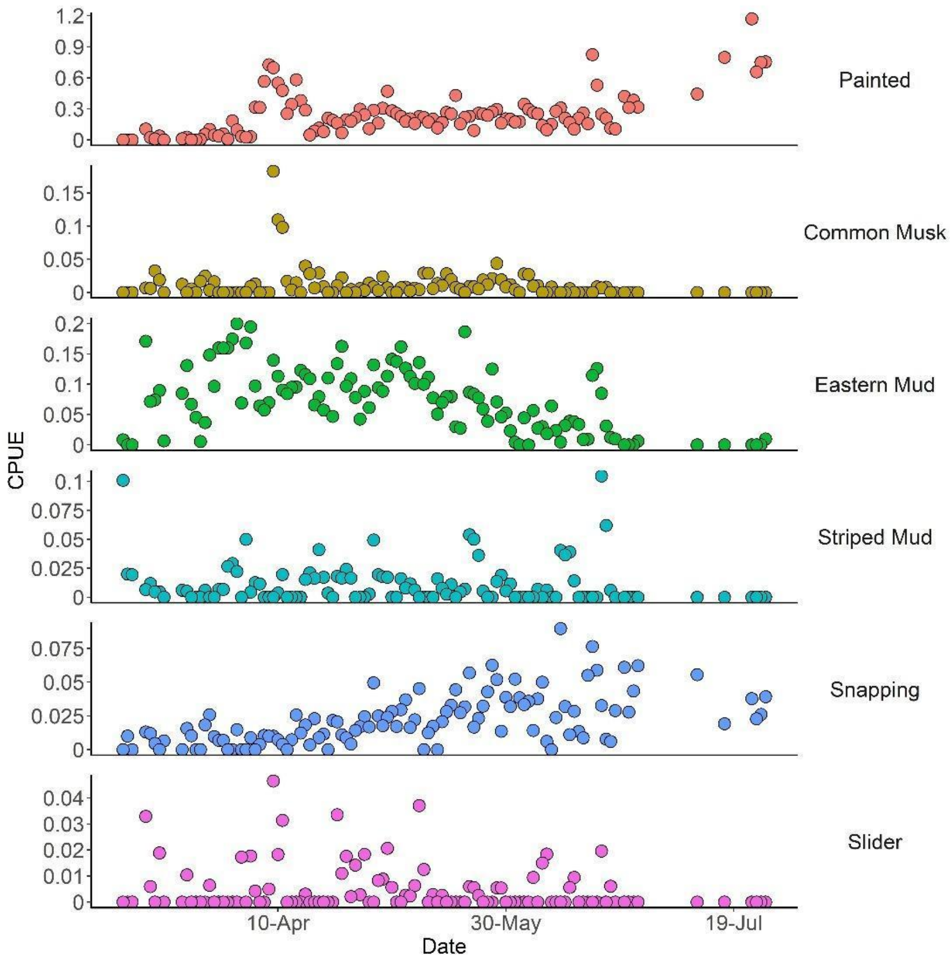


Figure 5-26. Catch per unit of effort (CPUE: captures/trap checks) by date and turtle species. Days with fewer than 100 trap checks have been removed. Source: Trap check.

CPUE of Painted and Snapping Turtles appeared to increase over the sampling period, while CPUE of Eastern Mud Turtles appeared to peak in May and then decrease. Because Eastern Mud Turtles were primarily captured in southern sub-regions, while Painted and Snapping Turtles were primarily captured in northern sub-regions of the eastern United States, we subset the data for these three species by sub-region to see if these patterns changed geographically (Figure 5-27). This changed the date range dramatically, especially in the northern Mid-Atlantic, where dates with at least 100 checks were confined to a week, obscuring any possible relationships.

After sub-setting by sub-region, we found significant linear and quadratic relationships between date and CPUE of Painted Turtles in New England and the Southeast. However, a positive linear regression appears to better suit the patterns seen in both New England ($F_{1,10}$=44.11, Adj. R^2=0.80, p=<0.001) and the Southeast ($F_{1,13}$=42.84, Adj. R^2=0.24, p=0.04; Figure 5-27). The consistently low CPUE of Painted Turtles in the Southeast makes this relationship unreliable. CPUE of Snapping Turtles had a quadratic relationship with date in New England ($F_{2,9}$=7.33, Adj. R^2=0.54, p=0.013), and a positive linear relationship in the southern Mid-Atlantic ($F_{1,64}$=37.01, Adj.

R^2=0.36, p=<0.001; Figure 5-27). CPUE of Eastern Mud Turtles had a quadratic relationship with date in the southern Mid-Atlantic ($F_{2,63}$=9.27, Adj. R^2=0.20, p=<0.001; Figure 5-27) and both a significant positive linear and quadratic relationship with date in the Southeast. Both relationships seemed plausible after examining the data: linear ($F_{1,13}$=7.51, Adj. R^2=0.32, p=0.017), quadratic ($F_{2,12}$=4.46, Adj. R^2=0.33, p=0.036; Figure 5-27).

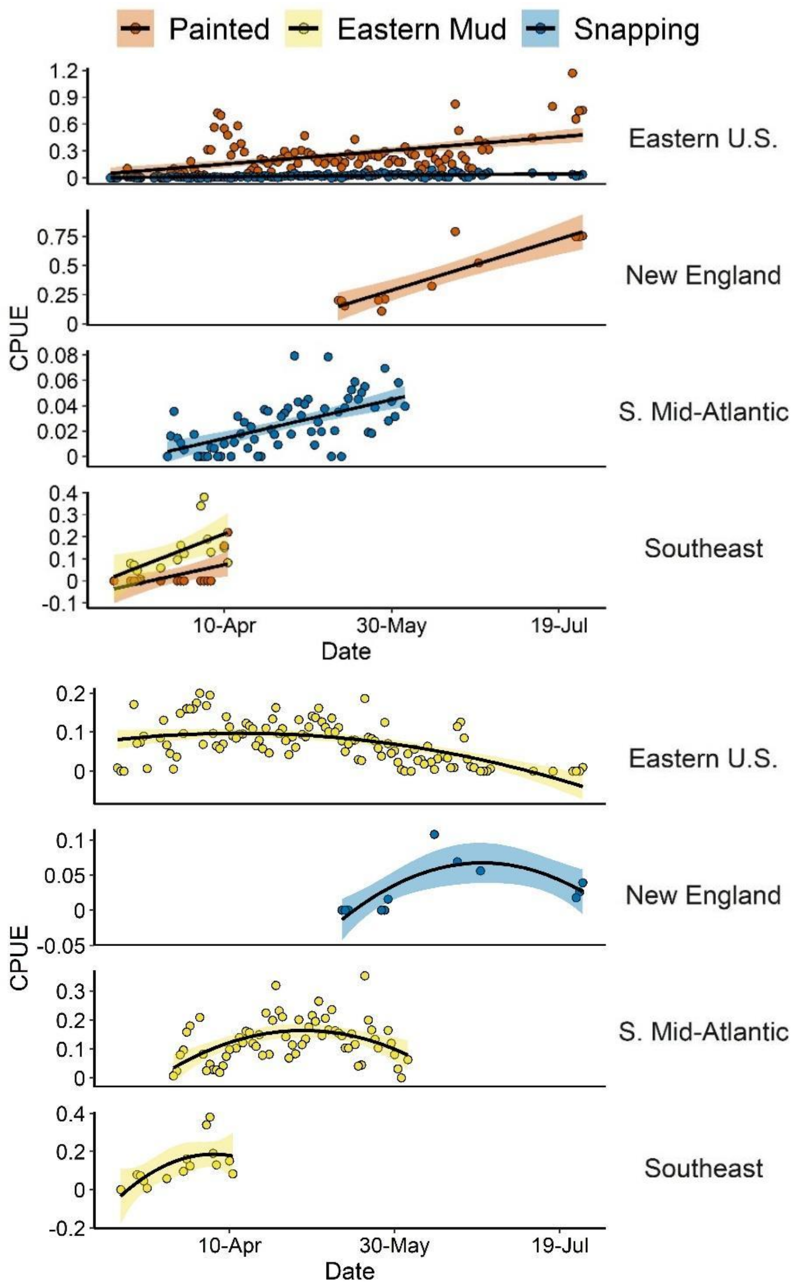


Figure 5-27. Catch per unit of effort (CPUE: captures/trap checks) by date and sub-region for Painted, Eastern Mud, and Snapping Turtle. Significant regressions and their 95% confidence intervals are shown (linear: top, quadratic: below). Source: Trap check.

Habitat Type and Percent Cover.—We also calculated CPUE of turtle species by habitat type (Figure 5-28). Again, any relationships may be complicated by the difference in sub-regions where these turtles were captured. We found that the highest CPUE for each species was within different habitat types. CPUE for Painted Turtles was highest in ponds, CPUE for Eastern Mud Turtles was highest in vernal pools, closely followed by ditches/pits, CPUE for Striped Mud Turtles was highest in forested wetlands, CPUE for Snapping Turtles was highest in emergent wetlands, CPUE for Sliders was highest in wetland ecotones, and CPUE for Common Musk Turtles was highest in ditches/pits (Figure 5-28).

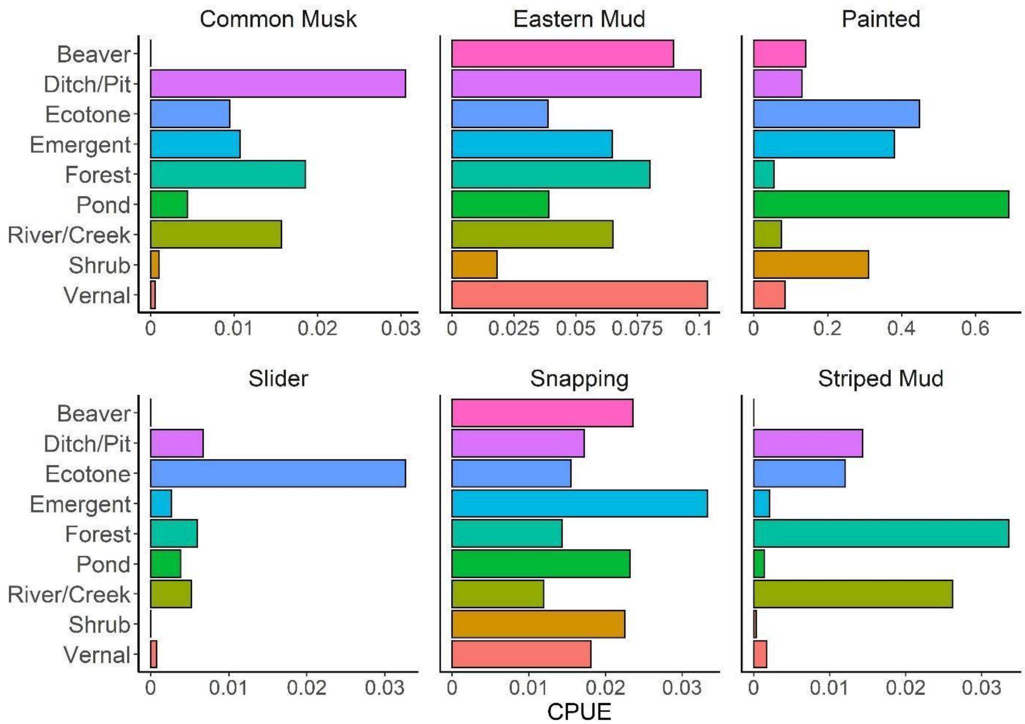


Figure 5-28. Catch per unit of effort (CPUE: captures/trap checks) by habitat type and turtle species. Source: Trap set/check.

We also evaluated relationships between the CPUE of species and percent cover of vegetation (Figure 5-29). Painted Turtle CPUE had a significant linear and quadratic relationship with percent canopy cover, but a negative linear relationship better fit the pattern in the data ($F_{1,10}$=64.93, Adj. R^2=0.85, p=<0.001; Figure 5-29). Painted Turtle CPUE also had a significant quadratic relationship with percent emergent herbaceous cover ($F_{2,9}$=4.75, Adj. R^2=0.41, p=0.039; Figure 5-29). Common Musk Turtle CPUE had a significant negative linear relationship with percent shrub cover ($F_{1,9}$=7.32, Adj. R^2=0.39, p=0.024; Figure 5-29). CPUE of Eastern Mud Turtles had significant linear and quadratic relationships with shrub cover, but a negative linear relationship better fit the pattern in the data ($F_{1,9}$=64.75, Adj. R^2=0.86, p=<0.001; Figure 5-29). Eastern Mud Turtle CPUE also had significant linear and quadratic relationships with both submergent herbaceous and canopy cover, but a quadratic term better fit the pattern for submergent vegetation ($F_{2,9}$=4.8, Adj. R^2=0.41, p=0.038; Figure 5-29), while a positive linear term appeared to better explain the relationship between CPUE and canopy cover ($F_{1,10}$=10.31, Adj. R^2=0.46, p=0.009; Figure 5-29). CPUE of Striped Mud Turtles also had significant linear and quadratic relationships with canopy cover, but a positive linear relationship better fit the patterns in the data ($F_{1,10}$=9.31, Adj. R^2=0.43, p=0.012; Figure 5-29). CPUE of snapping Turtles had a significant quadratic relationship with canopy cover vegetation ($F_{2,9}$=4.75, Adj. R^2=0.41, p=0.039; Figure 5-29), and both linear and quadratic relationships with emergent herbaceous cover. However, a positive linear relationship better explained the patterns in the data ($F_{1,10}$=14.88, Adj. R^2=0.56, p=0.003; Figure 5-29). Finally, the CPUE of sliders was negatively correlated with emergent herbaceous cover ($F_{1,10}$=4.96, Adj. R^2=0.26, p=0.05; Figure 5-29), and had significant quadratic and linear relationships with percent shrub cover. However, a positive linear regression better explained the patterns in the data ($F_{1,9}$=21.46, Adj. R^2=0.67, p=0.001; Figure 5-29).

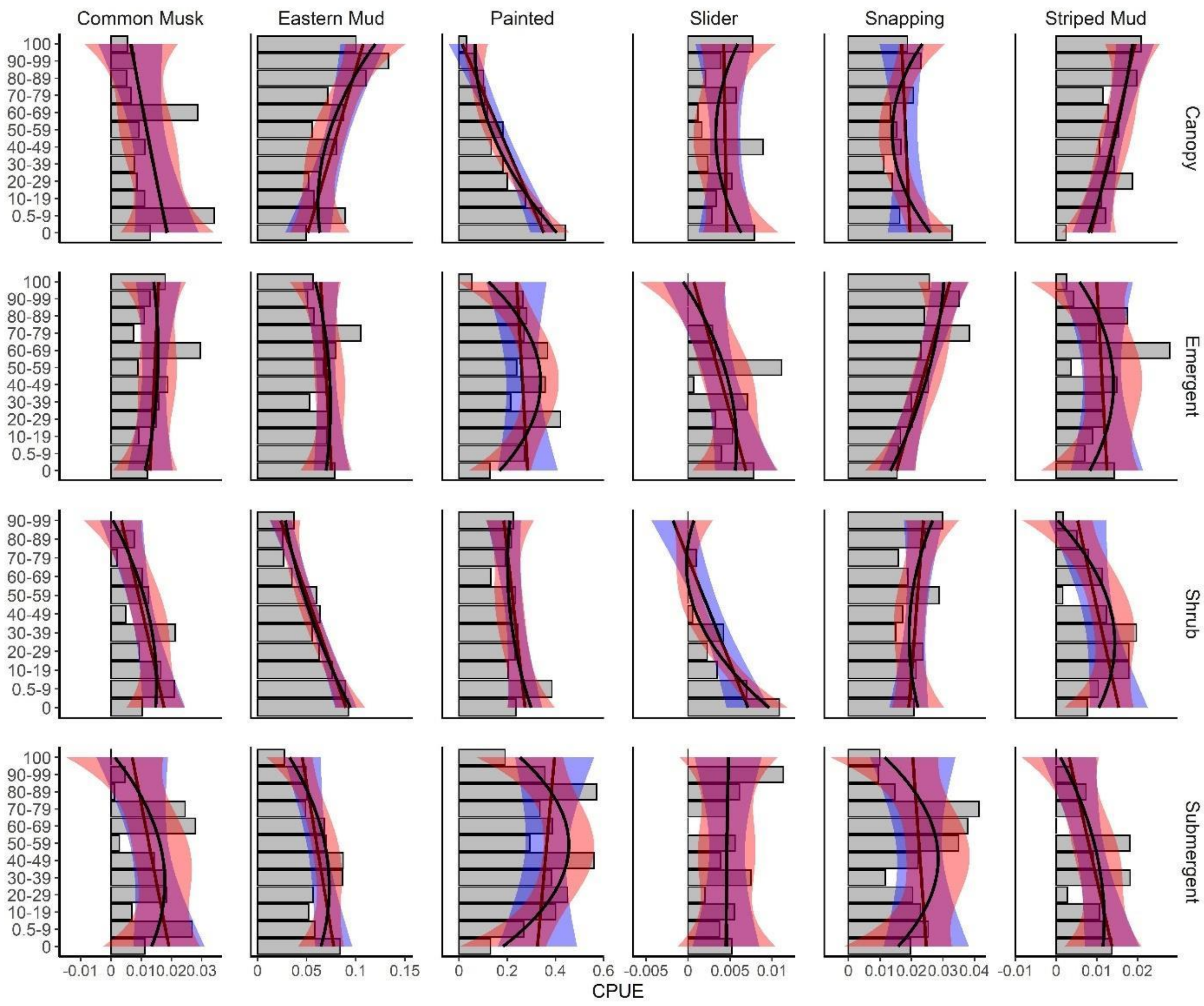


Figure 5-29. Catch per unit of effort (CPUE: captures/trap checks) for turtle species by percent cover range of different vegetation types. Red shaded regions show 95% confidence intervals for quadratic regressions while blue indicate linear regressions. Source: Trap set/check.

Co-occurrence with Spotted Turtles.—Finally, we examined patterns of co-occurrence between Spotted Turtles and other turtle species across the eastern United States and by sub-region (Figure 5-30). To do this we ranked species by naïve occupancy (number of sites at which they were detected) and by the number of sites at which they co-occurred with Spotted Turtles. While we present findings from the Southeast, co-occurrence of Snapping Turtles and Sliders is not reliable due to intentional exclusion of these species while using crab traps during Spotted Turtle sampling.

Spotted Turtles co-occurred most frequently with the most widely detected species across the eastern United States (Painted Turtle) and in New England (Painted Turtle), the northern Mid-Atlantic (Painted Turtle), and in the Southeast (Eastern Mud Turtle, Figure 5-30). However, in the southern Mid-Atlantic, Spotted Turtles co-occurred more frequently with Snapping Turtles, the second most widely detected turtle species in the sub-region (Figure 5-30). Expected co-occurrence was less predictable (less linear by ranked occurrence and co-occurrence) in southern sub-regions of the eastern United States, particularly in the Southeast (Figure 5-30).

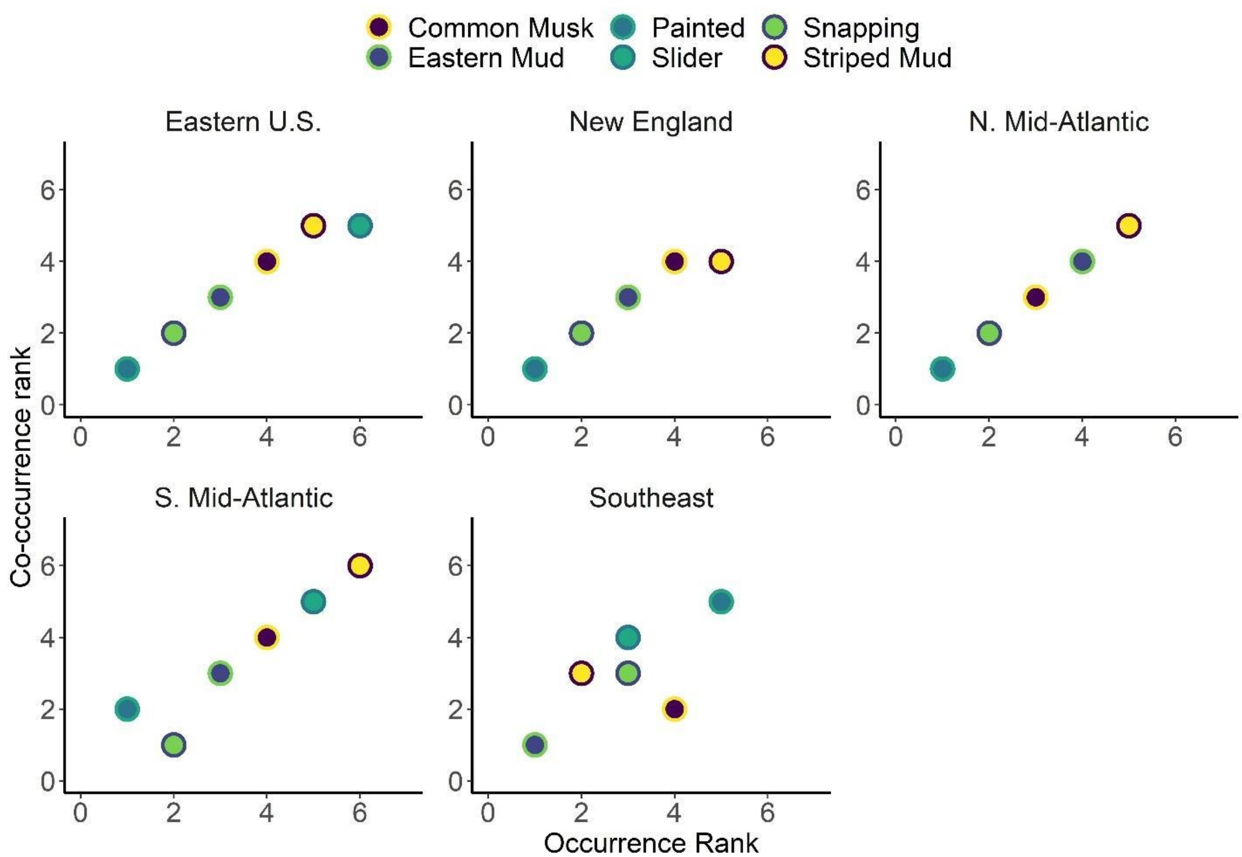


Figure 5-30. The occurrence rank (1 = highest, 6 = lowest) for turtle species, reflecting the number of sites at which they were captured, and their co-occurrence rank, reflecting the number of sites at which they co-occurred with Spotted Turtles, by sub-region. While we present findings from the Southeast, co-occurrence of Snapping Turtles and Sliders is not reliable due to intentional exclusion of these species while using crab traps during Spotted Turtle sampling. Source: Trap Check.

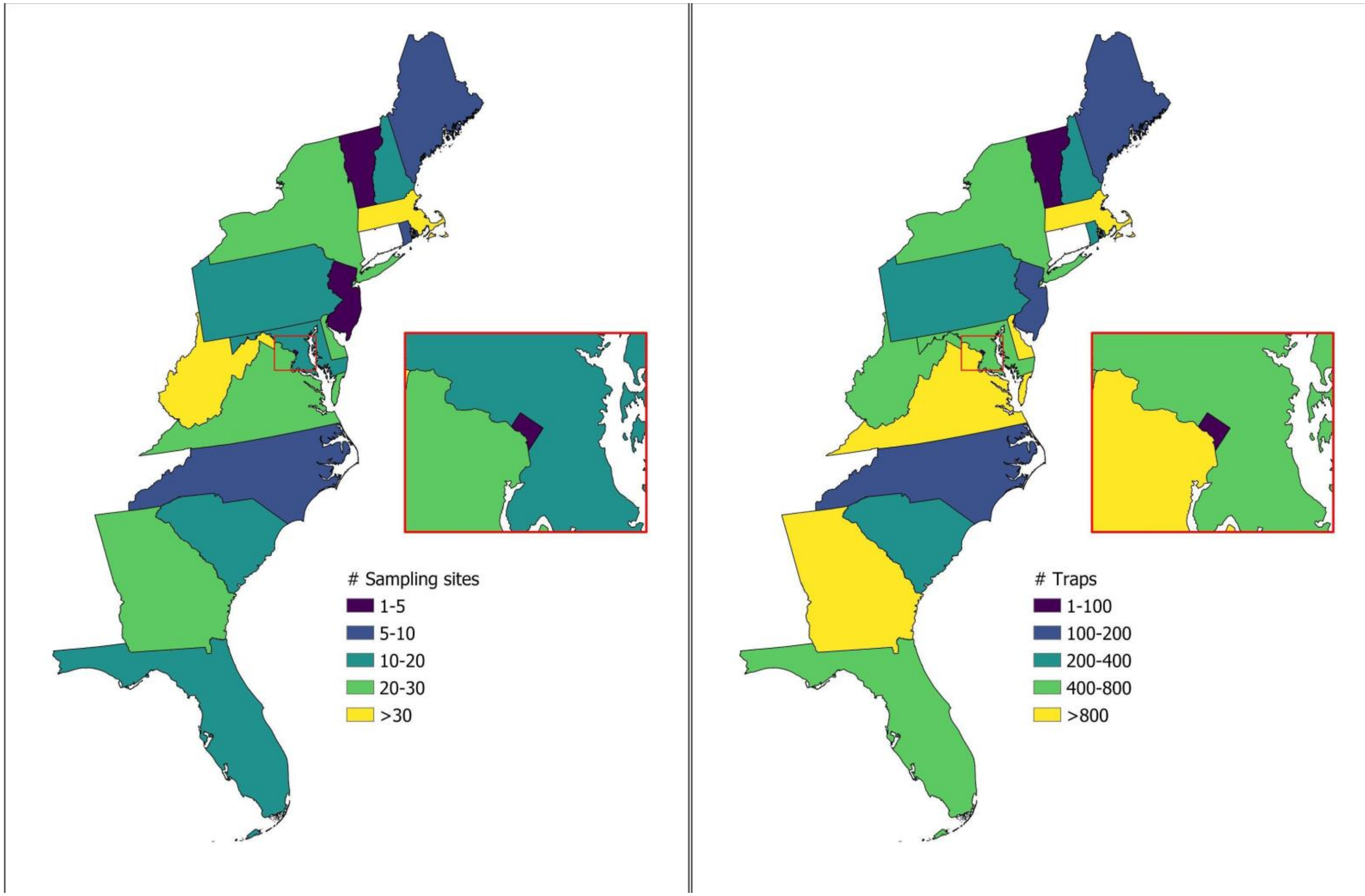
Naïve Occupancy of Turtle Species

Table 5-14. Number of sites where turtle species were captured, number of total sites surveyed, and resulting naïve occupancy by region. While we present findings from the Southeast, co-occurrence of Snapping Turtles and Sliders is not reliable due to intentional exclusion of these species while using crab traps during Spotted Turtle sampling. Source: Trap check

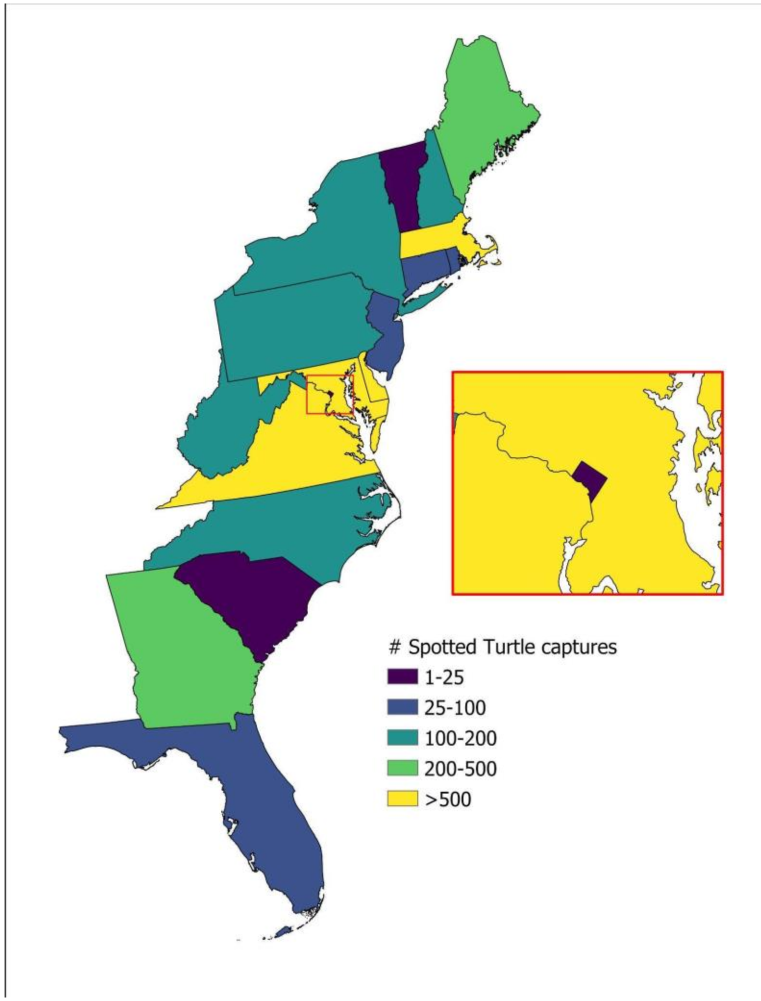
Turtle species	Region	# Sites where captured	# Total sites surveyed	Naïve occupancy
Spotted	Eastern U.S.	151	303	0.5
	New England	44	65	0.68
	N. Mid-Atlantic	32	62	0.52
	S. Mid-Atlantic	58	112	0.52
	Southeast	17	64	0.27
Common Musk	Eastern U.S.	49	303	0.16
	New England	2	65	0.03
	N. Mid-Atlantic	10	62	0.16
	S. Mid-Atlantic	17	112	0.15
	Southeast	20	64	0.31
Eastern Mud	Eastern U.S.	112	303	0.37
	New England	12	65	0.18
	N. Mid-Atlantic	4	62	0.06
	S. Mid-Atlantic	54	112	0.48
	Southeast	42	64	0.66
Painted	Eastern U.S.	181	303	0.6
	New England	58	65	0.89
	N. Mid-Atlantic	44	62	0.71
	S. Mid-Atlantic	76	112	0.68
	Southeast	3	64	0.05
Slider	Eastern U.S.	33	303	0.11
	New England	1	65	0.02
	N. Mid-Atlantic	1	62	0.02
	S. Mid-Atlantic	9	112	0.08
	Southeast	22	64	0.34
Snapping	Eastern U.S.	145	303	0.48
	New England	26	65	0.4
	N. Mid-Atlantic	34	62	0.55
	S. Mid-Atlantic	63	112	0.56
	Southeast	22	64	0.34
Striped Mud	Eastern U.S.	37	303	0.12

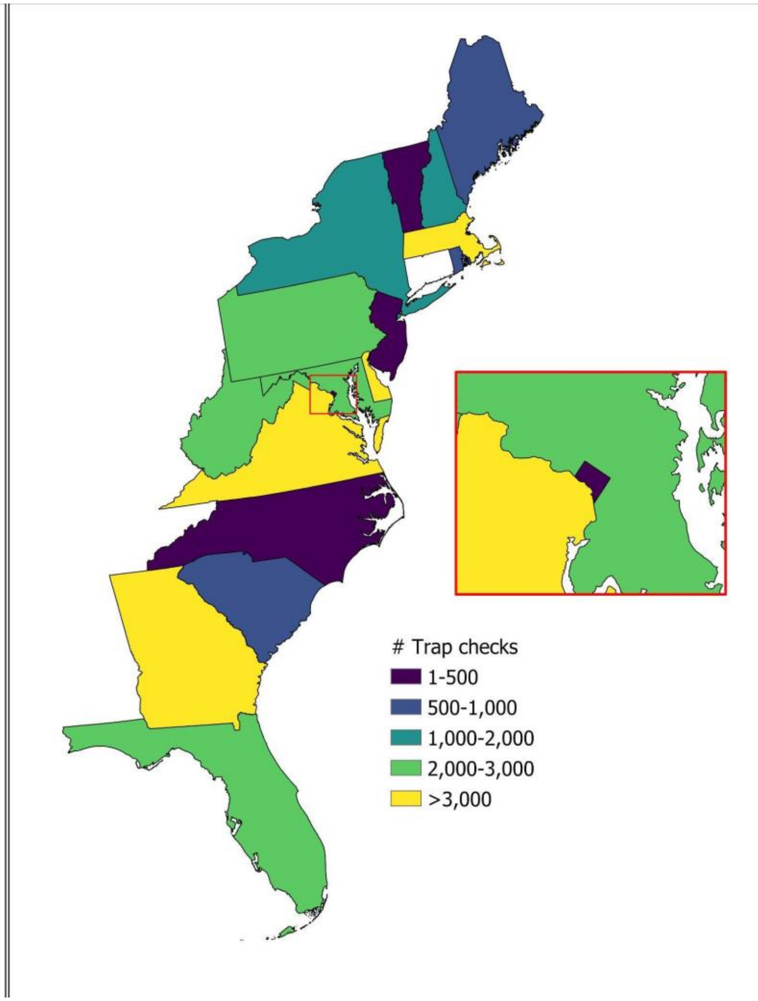
Turtle species	Region	# Sites where captured	# Total sites surveyed	Naïve occupancy
	New England	1	65	0.02
	N. Mid-Atlantic	1	62	0.02
	S. Mid-Atlantic	4	112	0.04
	Southeast	31	64	0.48

Sampling Summary Maps:

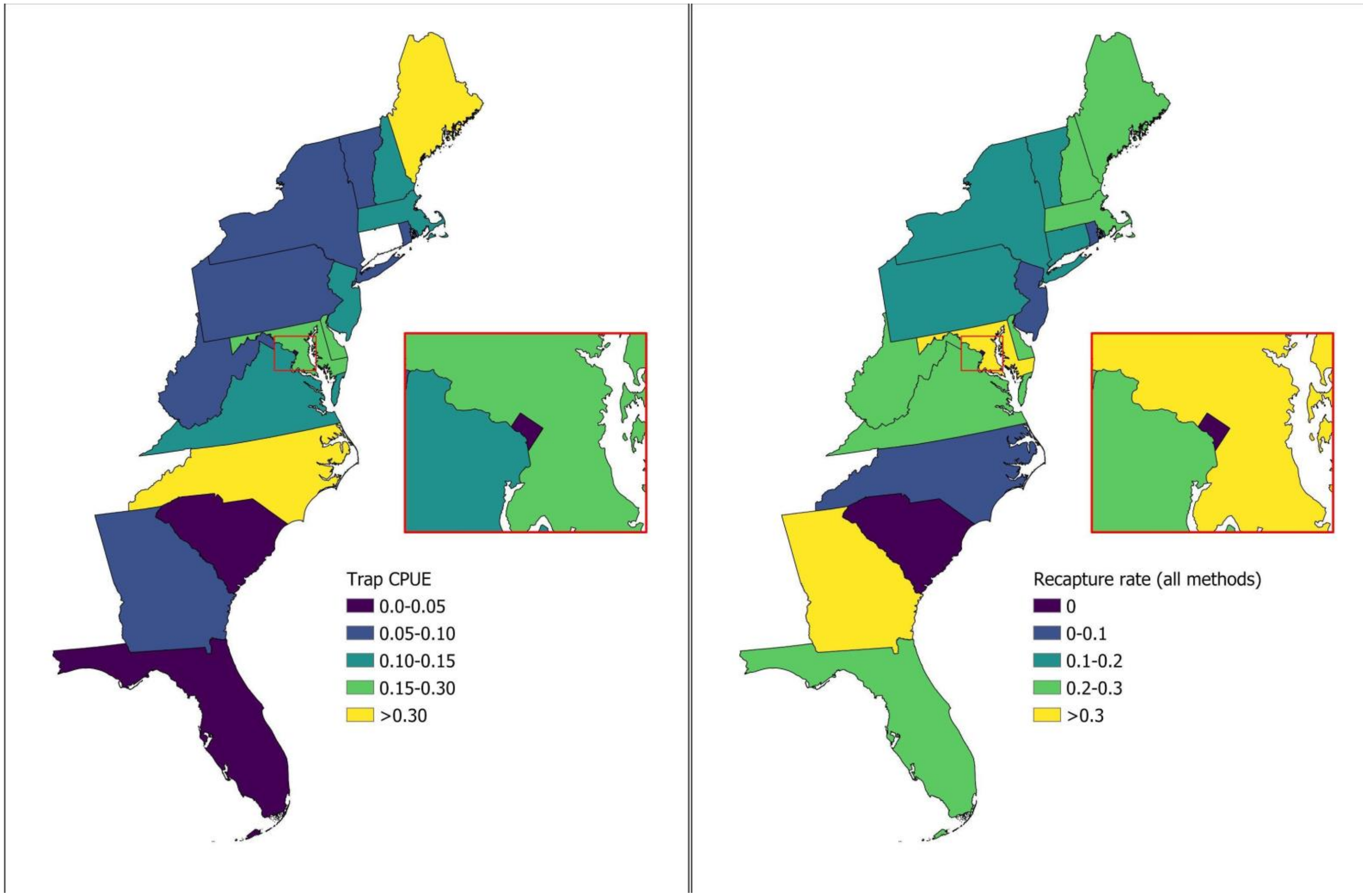


Map 5-1. A) Number of unique sites sampled for Spotted Turtles using traps within each state (Left). B) Number of traps set within each state (Right). The Map inset shows the District of Columbia. Unable to calculate number of sites or traps for Connecticut. Source: Trap set data from 2018–2021.





Map 5-2. A) Total Spotted Turtle captures within traps (Left) and B) number of trap checks completed within each state (Right). The Map inset shows Washington, D.C. Unable to calculate number of trap checks for Connecticut. Source: Trap check data (and individual for Connecticut) from 2018–2021.



Map 5-3. A) Catch per unit of effort (Spotted Turtle captures/trap check) across all sites and years within each state (Left). B) Recapture rate (recaptures/captures) by state (Right). The Map inset shows the District of Columbia. Unable to calculate CPUE for Connecticut. Source: Trap check (CPUE) and Individual (recapture rate) from 2018–2021.

Chapter 6. Multi-Scale Factors Influencing Spotted Turtle Abundance and Age Structure

H. Patrick Roberts

To further assess species status, we utilized the results of the standardized trap data described in Chapters 4 and 5 to assess the relationship between landscape characteristics and relative abundance of Spotted Turtle populations. **Note:** this Chapter summarizes the Spotted Turtle-specific results within a broader examination of the effects of landscape structure on the abundance of several turtle species, which is currently under review for publication in the peer-reviewed literature.

Methods

Population Sampling

Wetlands were sampled in accordance with the protocol outlined in Chapter 4. Only data collected and available through 2020 were utilized for the purposes of this analysis. Due to the competing objectives of the sampling protocol (i.e., to assess distribution of Spotted Turtles and therefore the need to trap in suitable Spotted Turtle habitat), we were unable to implement random sampling along *a priori* environmental or habitat gradients of interest. Surveyors often chose sampling sites that harbored known Spotted Turtle populations, supported suitable habitat, and/or were located within data-deficient portions of the Spotted Turtle range. We attempted to maximize geographic and ecoregional representativeness throughout the study area; however, sampling intensity varied depending upon the resources available to surveyors. A small proportion of sites were sampled more intensively with three separate four-day periods for a separate project. Therefore, to eliminate bias associated with increased sampling at these sites, we randomly selected one of the three, four-day periods for inclusion in analyses.

Environmental Covariates

Spatial Scales.—We calculated land cover, wetland, and landscape structure variables at multiple spatial scales (Jackson and Fahrig 2015; McGarigal et al. 2016), which were categorized into two levels: "local" and "landscape." The local level is intended to reflect scales that encompass, or are smaller than, the area of a typical Spotted Turtle home range 30–300 m at 30 m increments. The landscape level is intended to capture broader landscape-level patterns beyond the typical Spotted Turtle home range and included the following scales: 480, 960, 1,920, 3,840, and 7,680 m, since broadscale landscape pattern has been shown to correlate with the abundance of other, related turtle species (Roberts et al. 2021; Willey et al. 2022)

Land Cover.—Land cover variables included mean percent imperviousness, proportion road cover (hereafter referred to as "road density"), proportion hay/pasture cover, and proportion cultivated crop cover (Appendix 6-A). We calculated all land cover variables using the National Land Cover

Database (NLCD) raster data layers (Coulston et al. 2012; Yang et al. 2018). We removed commercial cranberry bogs from the cultivated crops variable, because this form of agriculture often provides suitable wetland habitat for Spotted Turtles. We estimated imperviousness by taking the mean of all cells within each spatial scale. We estimated the remaining variables by taking the proportion of cells that were classified as road, hay/pasture, or cultivated crops within each spatial scale. We calculated each variable for all cells on the landscape using the Focal Statistics tool in ArcGIS. We then extracted cell values for each trap location using the "raster" package (Hijmans and van Etten 2019) in R statistical software. Last, we calculated the mean for all traps within each reference plot.

Wetland Composition and Heterogeneity.—We used National Wetland Inventory (NWI; U.S. Fish & Wildlife Service 2020) data to calculate seven wetland variables that fell into three categories (Appendix 6-A): wetland amount (four variables), proportion ephemeral, and wetland diversity (two variables). The wetland amount category included the total area of (1) shallow palustrine wetlands (those classified as forest, shrub, or emergent), (2) forested wetlands, (3) shrub wetlands, (4) emergent wetlands (Appendix 6-B). The proportion ephemeral variable represented the proportion of all shallow palustrine wetlands that were ephemeral. We considered wetlands to be ephemeral if they were classified as temporarily flooded, seasonally flooded, or saturated wetlands (Appendix 6-B). The wetland diversity category included the Shannon's Diversity [Shannon and Weaver 1949] index for (1) shallow palustrine wetlands, and (2) shallow palustrine wetlands where permanent and ephemeral wetlands are treated as distinct wetland types (hereafter referred to as wetland-regime diversity). We calculated wetland-regime diversity because we suspected that landscapes with a diversity of not only wetland type, but also hydrologic regimes, may promote more robust populations. Before calculating each variable in R, we first buffered trap locations in ArcGIS by each spatial scale and measured the area and proportion of each wetland type and hydrological regime.

Wetland Configuration.— To characterize landscape structure, we rasterized the wetlands surrounding each sampling site using a 30-m cell size and characterized the degree of wetland aggregation using the Aggregation Index (AI), which is defined as the number of alike cell adjacencies divided by the total possible cell adjacencies (McGarigal et al. 2012). Because our goal was to characterize landscape-level patterns, we only estimated AI at larger spatial scales of ≥300 m. We calculated AI for all trap locations using the "landscapemetrics" package in R, then averaged values for each spatial scale within reference plots to produce a single measure of wetland aggregation for each scale and reference plot. The species examined in this study display varying wetland habitat associations; therefore, we calculated AI for all shallow palustrine wetlands.

Statistical Analyses

Abundance.— We related Spotted Turtle abundance to environmental covariates using hierarchical closed-population N-mixture models (Royle and Dorazio 2008) within the "unmarked" package in R (Fiske and Chandler 2011). We used each trap-night as a separate survey to estimate detection probability and account for bias associated with imperfect detection. To account for a lack of independence among reference plots within close proximity, we included "macrosite" as a random effect, which we defined as all reference plots separated by ≤2 km.

Detection covariates included air temperature, water temperature, day of year, accumulated growing degrees days, an interaction between day of year and growing degrees days, and trap-check visit (which ranged from one to five). Accumulated growing degrees represent the number of degrees the average daily temperature was above 50° F at the reference plot, summed across the entire year and was acquired from the USA National Phenology Network (2020). We scaled all continuous variables such that mean = 0 and SD = 1 to improve model convergence.

We used Akaike's Information Criterion corrected for small sample size (AICc; Burnham and Anderson 2002) to compare the performance of candidate models. First, to determine the most appropriate probability distribution for each species analysis, we compared zero-inflated Poisson and negative binomial distributions while also including a set of arbitrarily selected detection and site covariates to account for additional variation. The best performing distribution was used in all subsequent models.

We *a priori* established the maximum number of detection, wetland (amount, ephemerality, and diversity), and land cover covariates that would be allowed in any model, while considering sample size (to avoid overfitting models), as well as our desire to consider detection, wetland, and land cover covariates (Appendix 6-C). We also *a priori* selected a subset of the environmental variables that would be considered (Appendix 6-D). We considered variables highly correlated if $r > 0.7$ and removed the variable with the higher AICc value when comparing single-variable models.
To begin the model selection process, we first used the "MuMIN" package (Barton 2016) in R to select detection covariates by comparing all variable subsets within the maximum number of detection covariates allowed for that species (Appendix 6-C). We considered quadratic terms for air temperature, water temperature, and day of year. We selected the detection covariates with the lowest AICc score and included these within all subsequent models.

We expected that wetland characteristics would be most important in determining turtle abundance, and land cover variables of secondary importance. Furthermore, we expected that accounting for variation associated with wetland characteristics would be important in elucidating land cover relationships. Therefore, we first selected the best combination of wetland variables and held these variables constant within models while selecting land cover covariates.

Prior to wetland variable selection, we first determined the best performing spatial scale for each wetland variable. We considered both linear and quadratic terms during scale selection. We selected the scales with the lowest AICc value (Appendix 6-E). If no scale performed better than the null model for a variable, it was no longer considered during model selection. We selected wetland variables using the following process: (step 1) select the best combination of "wetland amount" variables, (step 2) select the best combination of variables when considering those from step 1 while also considering wetland ephemerality variables, and finally (step 3) select the best combination of variables when considering those from step 2 and wetland diversity variables.

Prior to land cover variable selection, we determined the best performing spatial scale for each variable while retaining selected wetland variables in all models. During scale selection, we considered linear terms as well as interactions with wetland aggregation at the same scale (e.g., interaction between road density within 300 m and AI 300 m; Appendix 6-F). Last, we compared all subsets of land cover variable combinations without exceeding the predetermined maximum number of variables per model (Appendix 6-C). We report all models with ΔAICc < 2 and consider covariates that occurred within these models strongly supported if 95% confidence intervals (CI) of coefficient estimates did not overlap 0 (Chandler et al. 2009).

Age Structure.—We related the proportion of captures that were juvenile to environmental covariates using generalized linear mixed models with a binomial error distribution. We used the "glmmTMB" package (Brooks et al. 2017) in R to fit all models. Similar to abundance analyses, we included "macrosite" as a random effect (see Abundance section above). We classified individuals as juvenile if they had <nine annuli and carapace length was <85 mm to account for situations where surveyors either misclassified, or forgot to record, age class. We also classified individuals as juvenile if they had >eight annuli, but carapace length <75 mm, because individuals may appear older with respect to annuli because additional annuli may occur within a year if, for example, resource availability is interrupted (Litzgus and Brooks 1998*c*). We restricted analyses to only include sites with ≥10 individuals captured (Gibbs and Steen 2005; Roberts et al. 2021).

Results

We recorded 4,929 detections of 12 turtle species across 531 reference plots from 2018–2020; this is a subset of the complete data collected and summarized in Chapter 5. We detected Spotted Turtles at 188 of 522 reference plots that were included within the analysis.

Spotted Turtle abundance displayed strong positive associations with wetland diversity (30 m) and wetland ephemerality (7,680 m) and showed a strong unimodal relationship with wetland-regime diversity (480 m); Table 6-1; Figure 6-1). Abundance was also strongly negatively associated with road density (480 m; Table 6-2; Figure 6-1). Abundance was negatively associated with cultivated crop cover (60 m) in every top model, although none of these were strong relationships (i.e., CI excluding 0; Table 6-2). Abundance was negatively associated with imperviousness (300 m) in one of three top models, but this was not a strong relationship. Hay cover (480 m) strongly interacted with wetland aggregation to affect abundance (Table 6-2; Figure 6-2), such that abundance was negatively associated with hay cover at low aggregations, but this relationship subsided as wetlands became more aggregated, and was even positive at highest aggregations (although there was greater error associated with estimates at high aggregations). Spotted turtle probability of detection displayed a strong positive association with water temperature and strong negative associations with accumulated growing degrees days, trap-check visit, and day of year (Figure 6-3).

We captured ≥10 turtles at 58 sites, and across these sites, 78 juveniles were captured, with the proportion of turtles that were juveniles ranging 0–0.37. The proportion of captures that were juvenile displayed a strong positive relationship with cultivated crops (90 m) and shallow palustrine wetland diversity (30 m) and strong negative relationships with road density (150 m) and the amount of emergent wetland (30 m; Table 6-1, 2; Figure 6-4).

Table 6-1. Parameter estimates for wetland variables of best performing models of Spotted Turtle abundance and age structure (proportion juvenile) throughout the eastern United States.

Response variables		Amount (area)	Ephemerality	Diversity	
	Covariates		Shallow palustrine 7680m	Shallow palustrine 30m	Wetland-regime $480m^2$
Abundance	Model 1		**1.311 (0.283)**	**0.250 (0.098)**	**-0.259 (0.092)**
	Model 2		**1.283 (0.287)**	**0.261 (0.100)**	**-0.260 (0.093)**
	Model 3		**1.274 (0.284)**	**0.265 (0.100)**	**-0.262 (0.093)**
Juvenile proportion	Covariates	Emergent 30^2		Shallow palustrine 30^2	
	Model 1	**-2.852 (0.953)**		**2.256 (0.558)**	

Table 6-2. Parameter estimates for land cover variables of best performing models of Spotted Turtle abundance and age structure (proportion juvenile) throughout the eastern United States.

Response variable		Land cover						DeltaAICc	weight
	Covariates	Road density 480m	Cultivated crops 60m	Hay 480m	Aggregation index 480m	Interaction hay*AI	Impervious 300m		
Abundance	Model 1	**-0.422 (0.114)**	-0.906 (0.5)	-0.135 (0.123)	0.160 (0.138)	**0.378 (0.169)**		0	0.44
	Model 2	**-0.390 (0.119)**	-0.919 (0.506)				-0.417 (0.308)	0.63	0.32
	Model 3	**-0.444 (0.114)**	-0.916 (0.508)					1.114	0.25
Juvenile proportion	Covariates	Road 150	Cultivated Crops 90						
	Model 1	**-5.967 (2.422)**	**1.633 (0.543)**					0	1

Table 6-3. Detection covariates for Spotted Turtle abundance models. All covariates were strong predictors of detection probability within all models.

Species		Detection Covariates			
	Covariates	GDD	Visit	Water temp	Date
Spotted Turtle	Model 1	-0.806 0.172	-0.220 0.0304	0.391 0.0752	-0.753 0.1196
	Model 2	-0.919 0.1525	-0.218 0.0304	0.381 0.0740	-0.776 0.1180
	Model 3	-0.922 0.1523	-0.218 0.0304	0.379 0.0740	-0.776 0.1180

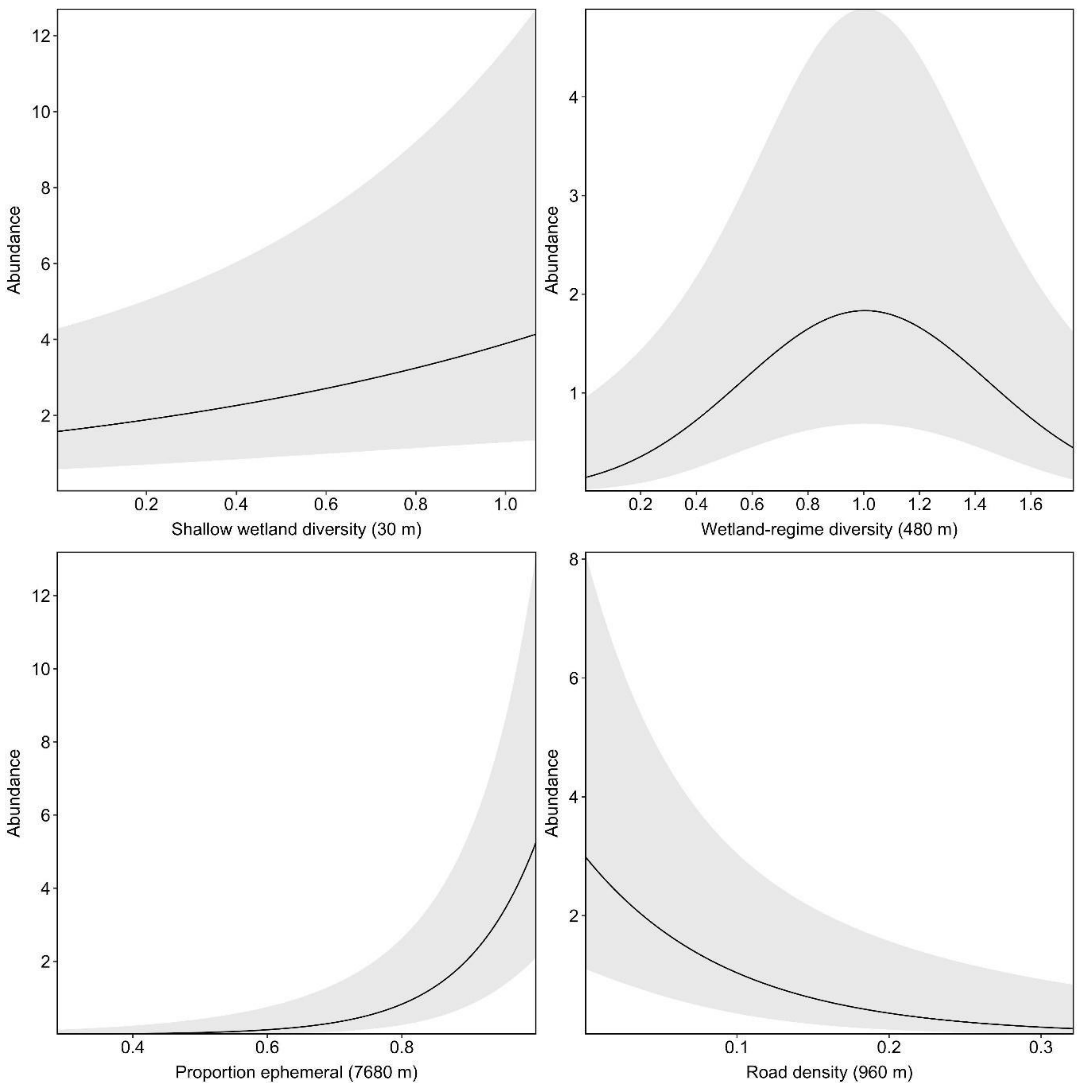


Figure 6-1. Spotted Turtle abundance in relation to environmental covariates within top performing models.

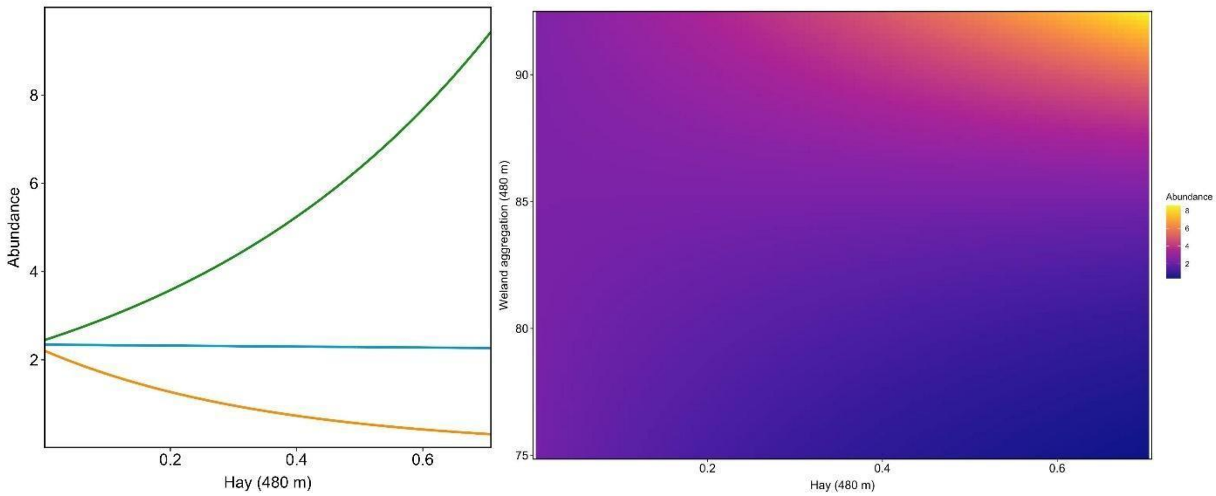


Figure 6-2. Spotted Turtle abundance in relation to proportion of hay (480 m) and wetland aggregation (480 m). Left plot shows the relationship with hay at low wetland aggregation (0.25 quantile, orange line), median aggregation (blue), and high aggregation (0.75 quantile, green line). The right plot depicts abundance with color in relation to wetland aggregation and hay.

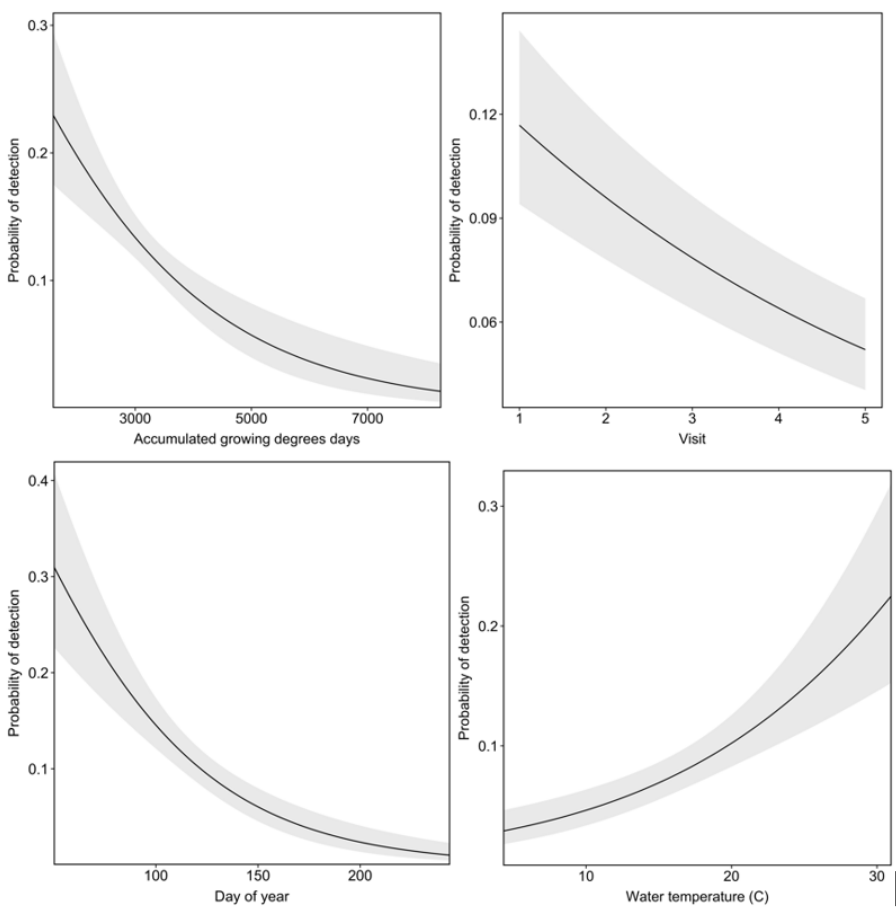


Figure 6-3. Spotted Turtle probability of detection in relation to environmental covariates.

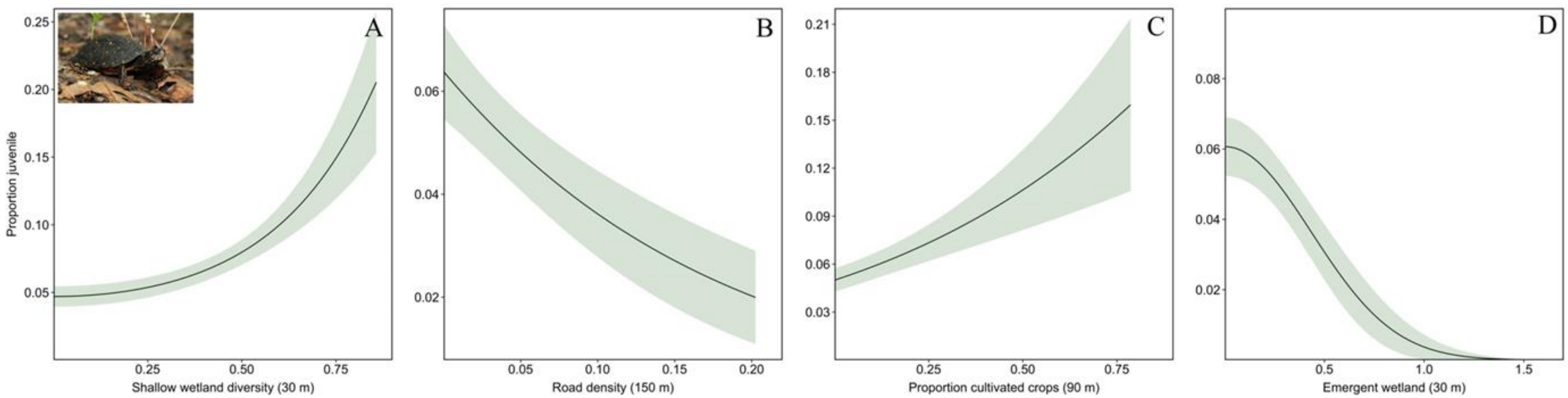


Figure 6-4. Spotted Turtle juvenile proportion in relation to land cover and wetland covariates.

Chapter 7. Population Estimation of Spotted Turtle Sites Using Capture-Mark-Recapture

John C. Garrison, Lisabeth L. Willey, and Molly K. Parren

To complement the broad-scale population assessment described in Chapter 6, we used loglinear models to estimate site-specific population abundances for sites with sufficient trap capture data. Sites trapped using the standardized protocol (DA or TRA sites) were selected for population abundance modeling using a capture-mark-recapture analysis. In an effort to include as many states and sites as possible, we included sites where five or more turtles were captured and had at least two recaptures; 80 sites met these criteria.

Methods

Abundance estimates were calculated for each of the 80 sites using the M0 model and the function closedp.bc in the Rcapture package (Baillargeon and Rivest 2012). This function applies a bias correction as described in Rivest and Levesque (2001) to Poisson regression models without accounting for any sources of variation in capture probabilities. The M0 model was used to ensure a consistent model could be applied across all sampling sites. Population abundance estimates and log of abundance estimates were displayed using the ggplot2 package (Wickham 2016). Capture histories for each site were created in Microsoft Excel (2013) and all statistical analyses were conducted in R (R Core Team 2021).

We related abundance estimates to catch per unit effort (CPUE; number of Spotted Turtles captured in traps/number of trap checks) at each site using linear regression and evaluated differences between three subregions: New England (Maine, New Hampshire, Massachusetts, and Rhode Island), the Mid-Atlantic (New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and West Virginia) and the Southeast (North Carolina, Georgia, and Florida; Map 7-1).

Results

Abundance estimates for the 80 sites ranged from 6.8 (SE=1.2) at a site in Delaware to 414 (SE=141) at a site in North Carolina, with a median of 48.45 (Figure 7-1). Nineteen or 23.75% of the sites were estimated to have over 100 turtles. Population estimates and confidence intervals for individual sites are presented in Figures 7-2 to 7-5 at the end of this chapter. Sites are separated into four groups by abundance estimates to allow the scale on the plots to be shifted, allowing for all abundance estimates to be visible in the figures. Tables detailing population estimates are included in Appendix 7-A.

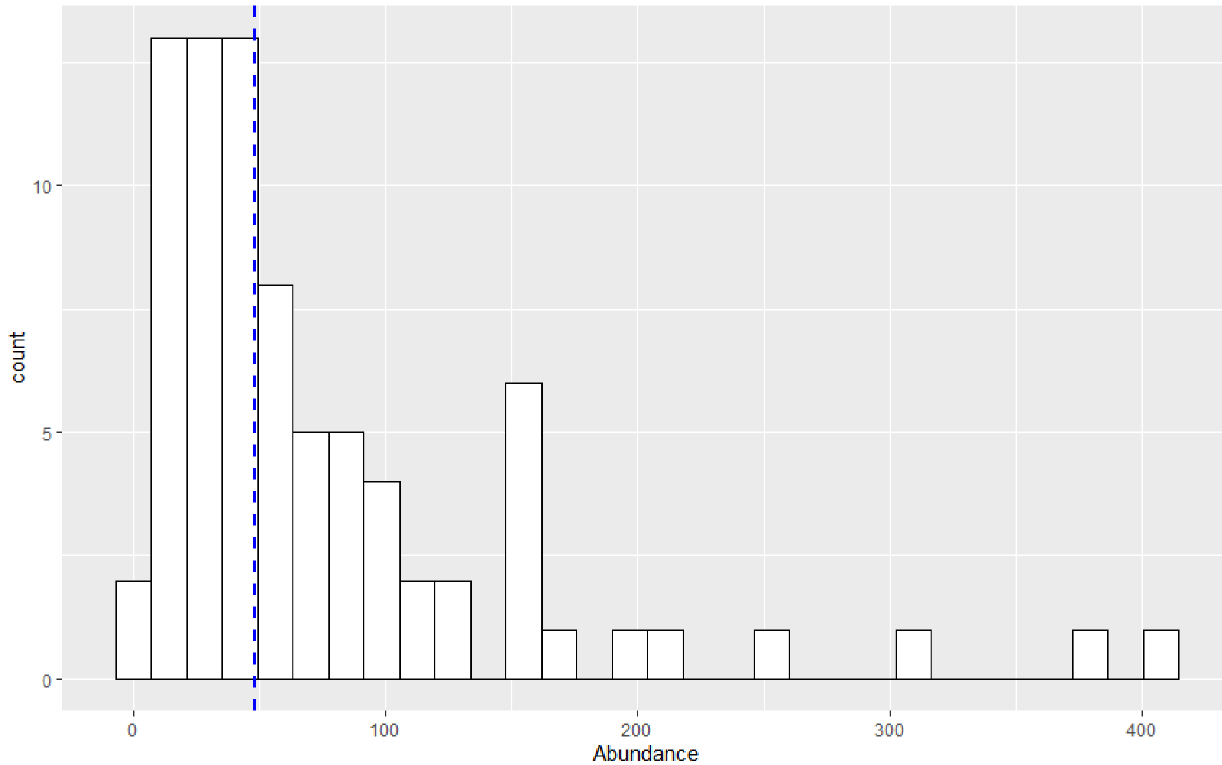


Figure 7-1. Histogram of abundance estimates from mark-recapture data at the 80 sites with sufficient recapture data. Estimates ranged from 6.8 at a site in Delaware to 414 at a site in North Carolina, with a median of 48.45 (depicted by the dotted blue line).

Abundance estimates varied by region, with the median abundance in the Mid-Atlantic being the highest (60.3), followed by the Northeast (49.2), and the Southeast (43.8). Although the Southeast had the sites with the highest estimates, there were also more sites in that region with much lower abundance estimates (Figure 7-6).

Log transformed catch per unit effort at a site was generally a good predictor of log transformed abundance estimates, though this relationship did vary slightly by region (Figure 7-7)

Discussion

The models we used to estimate abundance assume that a population is closed and that there is equal catchability of all individuals within a site. A closed population does not experience recruitment, mortality, immigration, or emigration during the course of sampling (Seber 1992; Iijima 2020; Newman et al. 2014). Because Spotted Turtles are long-lived with high annual survival, and recruitment and mortality are likely low throughout a single field season, we believe that we meet those assumptions of a closed population (Ernst and Lovich 2009; Edmonds et al. 2021; Lancia et al. 2005). And while trapping locations typically consisted of four 200 m radius reference plots totaling 50.3 ha, the mean annual movement distances for Spotted Turtles are typically much less than 300 m (see Table 2-2). Therefore, we also believe that we meet the assumptions of no immigration of emigration of a closed population within the timescale of sampling (Chandler et al. 2019; Kaye et al. 2001; Milam and Melvin 2001; Pollock 1982).

The assumption of equal catchability requires that each turtle within a site, regardless of age, sex, or other characteristics, has the same chance of being captured (and recaptured), and that probability does not change over the course of sampling (Cormack 1966; Pollock et al. 1990). This assumption is likely violated (Table 7-1). For example, the recapture rate for adults across the eastern United States was 0.305, while that of juveniles was 0.13. These differences could bias results. However, there is likely a great deal of variation between sites and across the region, and. Therefore, when trying to apply a single, consistent model across all sites, equal catchability is a reasonable assumption to make rather than trying to parameterize a unique model at each site or by sex; particularly given low sample sizes and limited data (Koper and Brooks 1998; McKnight and Ligon 2017).

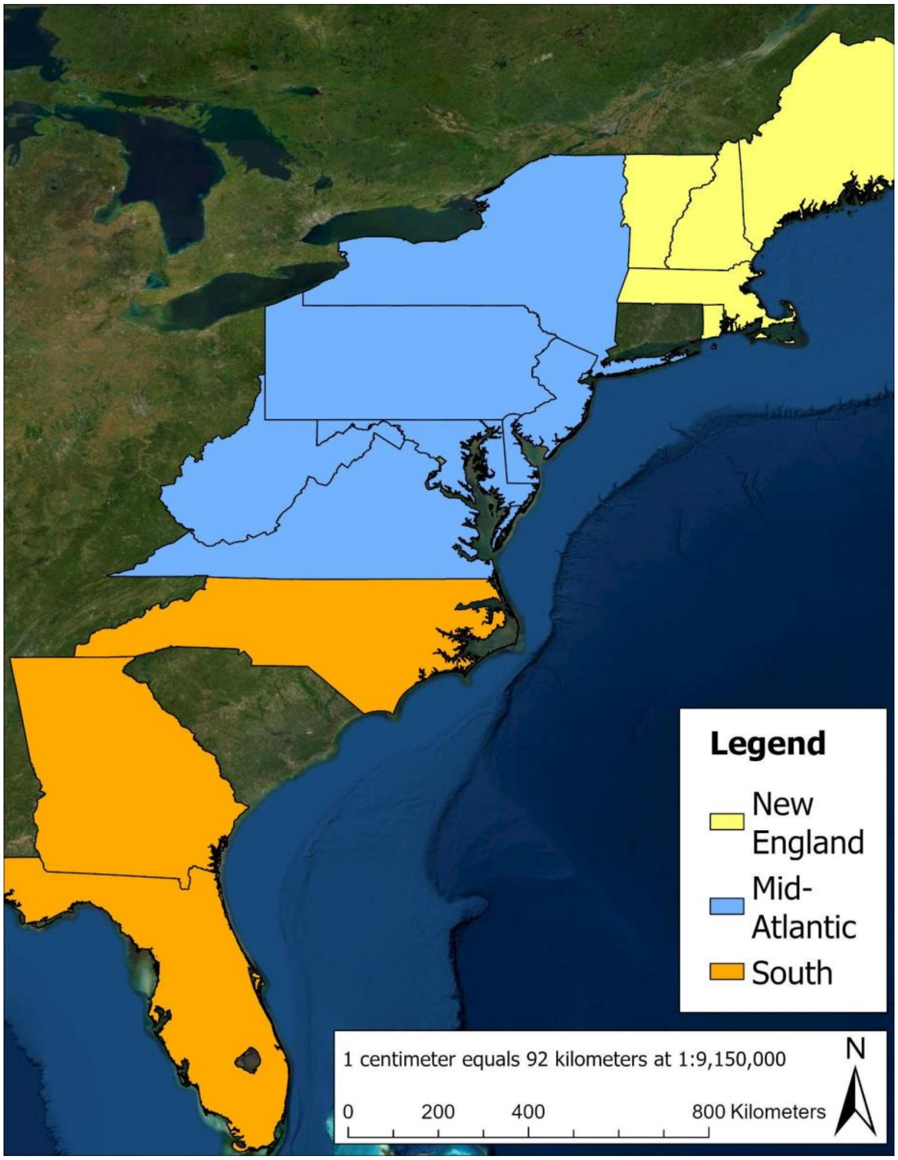
Table 7-1. Total number of turtle captures and individuals captured within traps at the 80 sites used in this analysis, and their associated recaptures and recapture rate (recaptures/captures) for adult and juvenile Spotted Turtles by sub-region and across the eastern United States.

Region	Age Group	Captures	Individuals	Recaptures	Recapture rate
Mid-Atlantic	Adult	2,022	1,424	598	0.296
New England		774	569	205	0.265
Southeast		322	174	148	0.46
Eastern U.S.		3,118	2,167	951	0.305
Mid-Atlantic	Juvenile	155	141	14	0.09
New England		83	69	14	0.169
Southeast		39	31	8	0.205
Eastern U.S.		277	241	36	0.13

Other factors also complicate estimates. Knowledge of a site might increase both capture and recapture rates, as researchers may place traps at known areas of high density. This sampling bias could increase or decrease estimates, depending on recapture rates (Ream and Ream 1966). Differences in habitat, season, and weather throughout the large study area might also alter detection, capture, and recapture rates (Chandler et al. 2020; Haxton and Berrill 2001; Lovich 1988). Sardines were used as bait, which may have influenced the detection, capture, and recapture rates as well (Mali et al. 2012, 2014; Oxenrider et al. 2019). These estimates represent only a snapshot in time; as additional sampling occurs at sites over time, and in additional areas of sites, population estimates and confidence around them are likely to change.

As noted in Table 7-1, capture and recapture rates varied considerably across the region, and some sites with high levels of both yielded estimates with tight confidence intervals, while others had much wider confidence intervals. For sites with sufficient data, additional models tailored to each site that consider capture heterogeneity may be warranted. Additionally, the use of spatially explicit capture recapture (secr) as well as open population models could be explored, particularly as more data are collected (Borchers and Efford 2008; Chandler and Clark 2014; Enneson and Litzgus 2009; Muñoz et al. 2016).

Results suggest that the sampling protocol, while not perfect, allows researchers to distinguish between very high abundance and relatively low abundance populations in some cases. These data serve as a baseline population estimate for these 80 sites and can be used to assess trends over time, albeit with greater confidence at some sites than others.



Map 7-1. States with sites that were included in the capture-mark-recapture analysis separated into three sub-regions New England (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island), Mid-Atlantic (New York, Pennsylvania, New Jersey, Delaware, Maryland, West Virginia, Virginia), and South (North Carolina, Georgia, Florida).

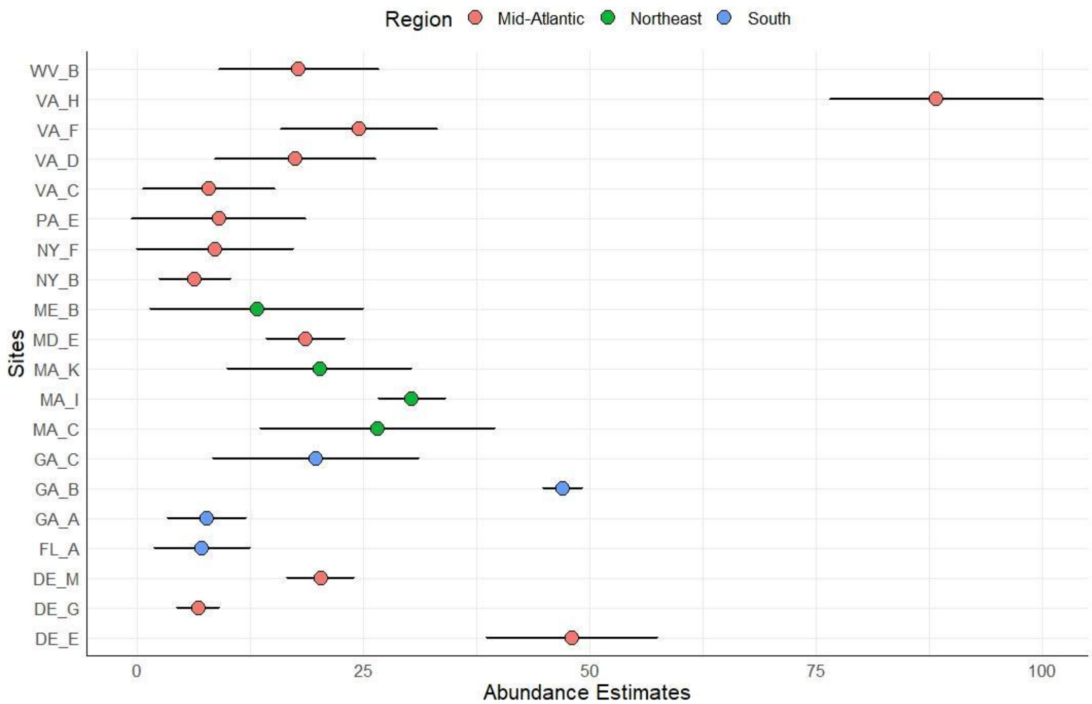


Figure 7-2. Population estimates for group A. (Sites are separated into four groups by abundance estimates to allow the scale on the plots to be shifted, making lower abundance estimates visible in the figures).

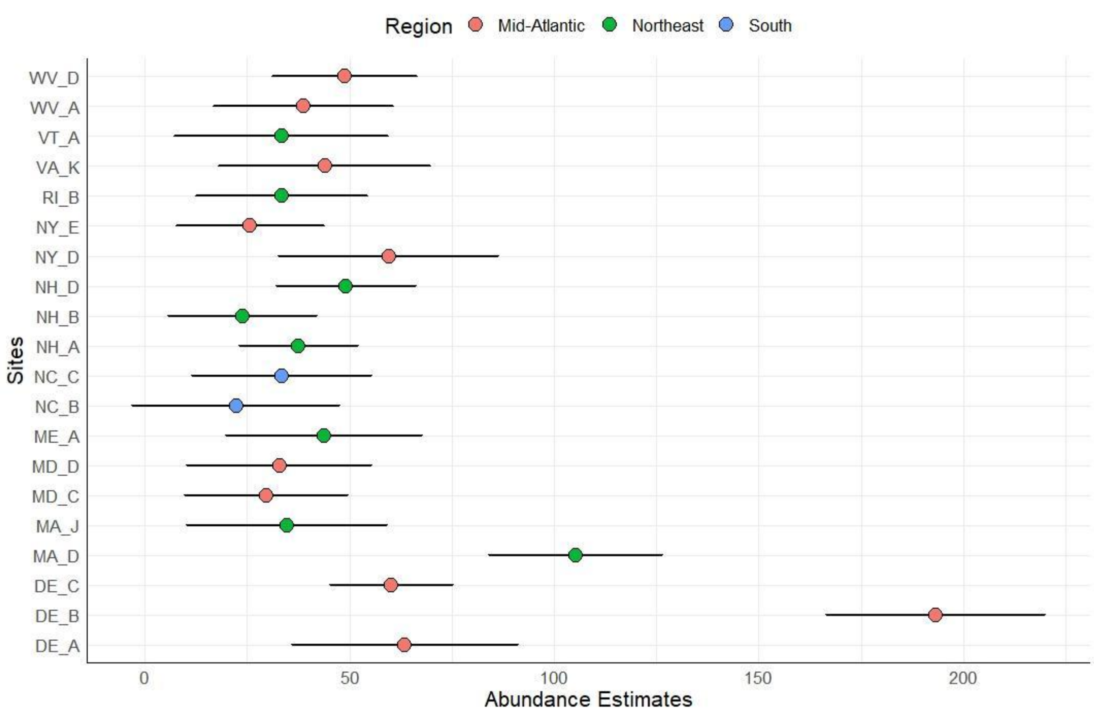


Figure 7-3. Population estimates for group B. (Sites are separated into four groups by abundance estimates to allow the scale on the plots to be shifted, making lower abundance estimates visible in the figures).

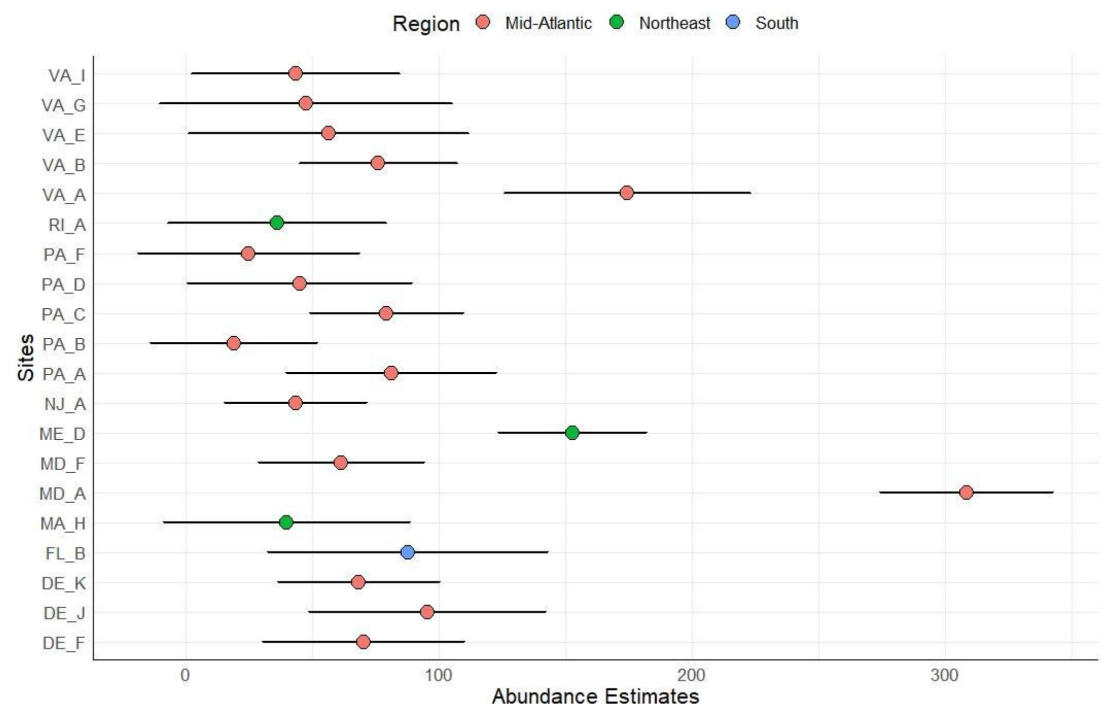


Figure 7-4. Population estimates for group C. (Sites are separated into four groups by abundance estimates to allow the scale on the plots to be shifted, making lower abundance estimates visible in the figures).

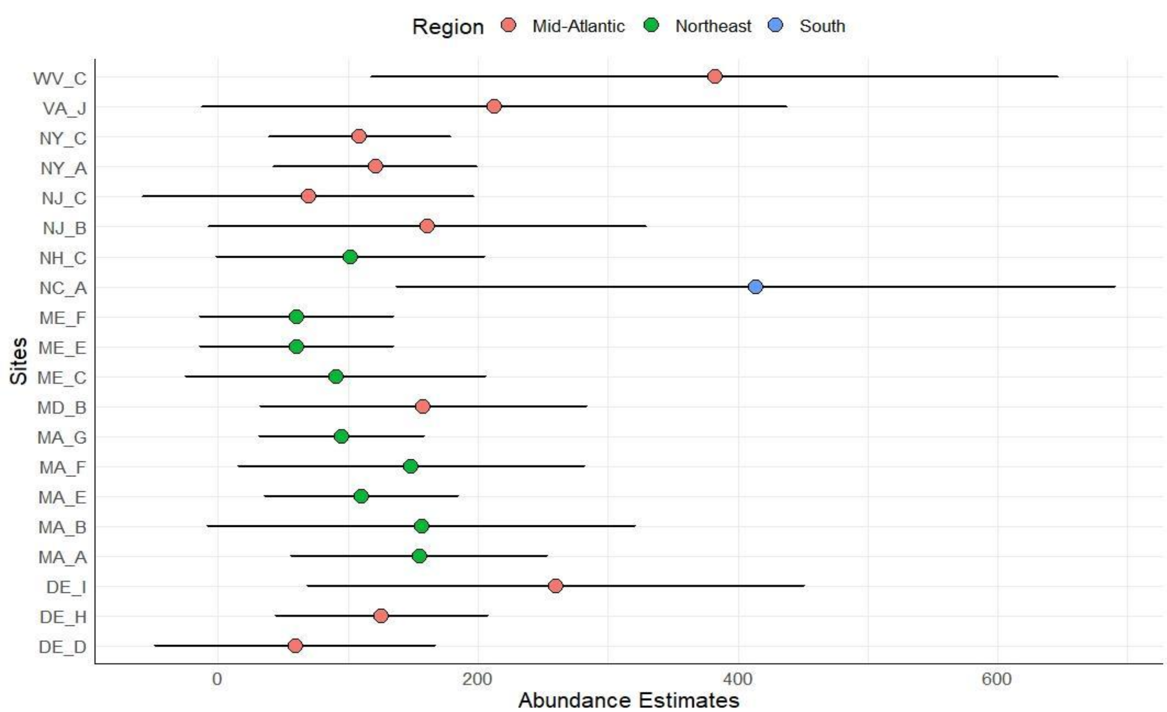


Figure 7-5. Population estimates for group D. (Sites are separated into four groups by abundance estimates to allow the scale on the plots to be shifted, making lower abundance estimates visible in the figures).

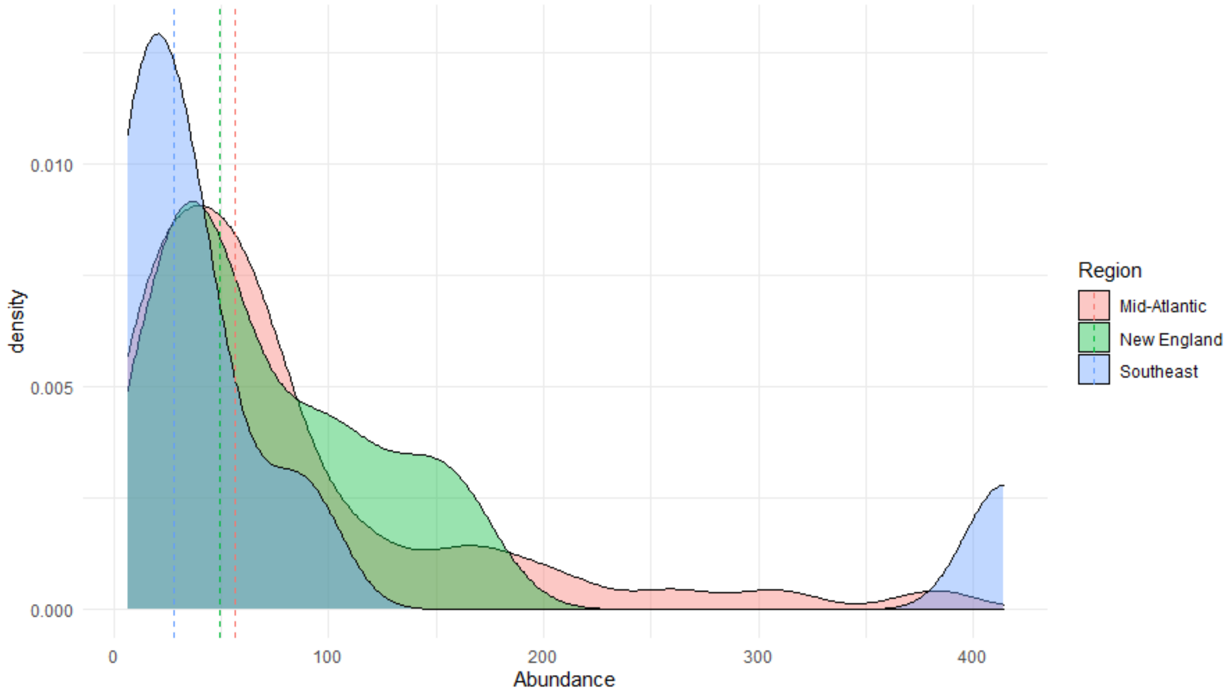


Figure 7-6. Density plot of abundance estimates by subregion, with medians for each region displayed by the dotted lines.

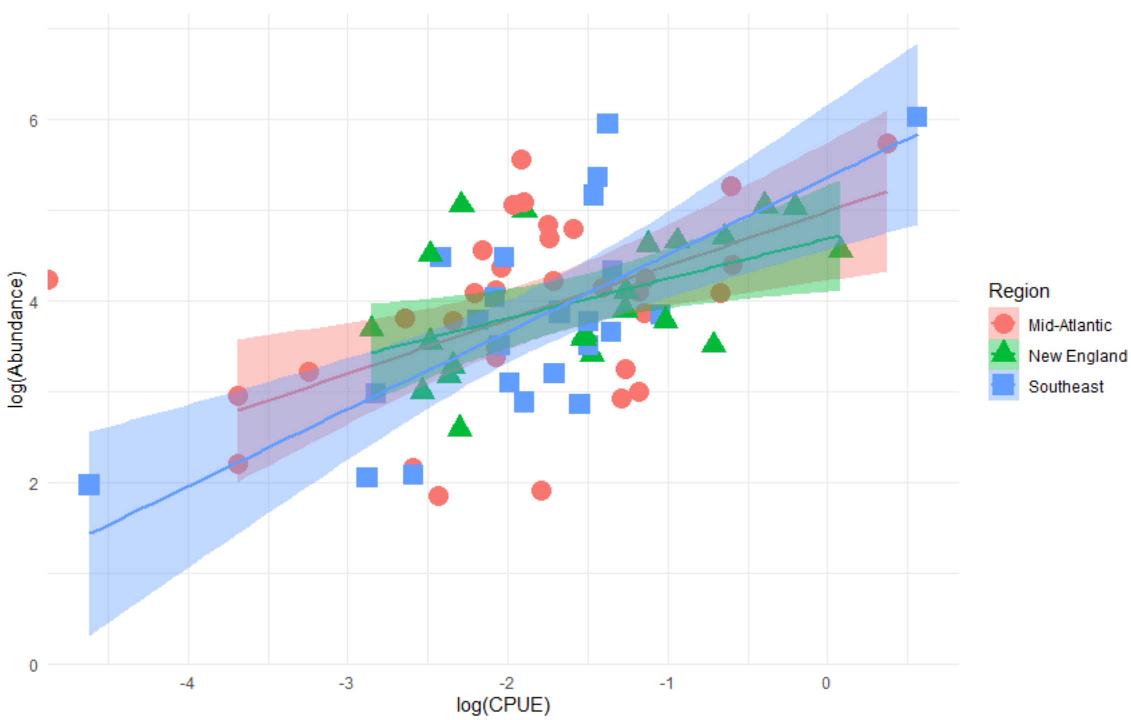


Figure 7-7. Log of abundance estimates based on mark-recapture data for the 80 Spotted Turtle sites with sufficient data to build loglinear models, as a function of log catch per unit effort (CPUE; number of Spotted Turtles in traps/number of trap nights at that site), by region.

Part IV. Environmental Change and Spotted Turtle Populations

Threats documented or expected to influence the viability of Spotted Turtle populations are complex and numerous, and vary spatiotemporally in importance (see Chapter 1, Appendix 1-A). Most prominently, these include habitat loss and fragmentation, hydrologic alterations, illegal collection, subsidized depredation, invasive species, and pathogens. In this section, we further evaluate the primary threats of environmental change influencing the persistence of representative Spotted Turtle populations. To do this, we examine the magnitude of influence of wetland loss in the region and assess how land-use conversion and climate change may be influencing Spotted Turtle distribution and demographics by conducting a variety of modeling approaches.

Chapter 8. Evaluation of Habitat Loss Through Land-use Change and Protected Status of Spotted Turtle Sites

Molly K. Parren and Lisabeth L. Willey

Introduction

As detailed in Appendix 1-A, the highest-ranking threats to Spotted Turtles (development, habitat loss, and roads) are attributed to land-use and associated land cover change. In this chapter, we examine this threat by using GIS layers to estimate the amount of known Spotted Turtle habitat that has been impacted by development. The Spotted Turtle occurrence records we gathered for site delineation (detailed in Chapter 2 and expanded upon in Chapter 13) were composed of both current and historical records. To further explore patterns between land cover and Spotted Turtle presence in the eastern United States, we compared mean values for land cover characteristics at Spotted Turtle sites with recent observations (current) and at sites where the species has not been seen in recent years (historical). We also assessed the potential for future change by evaluating the protected status of delineated sites.

Spotted Turtle Site Age

We used 11,957 individual Spotted Turtle records and element occurrences (EOs) from a variety of sources (see Part II) to delineate sites in the eastern United States. Following a standardized delineation process (see Chapter 2: Site Delineation), 2,351 sites were mapped and attributed with the most recent year that a Spotted Turtle was observed at that site ("Year of Record"). Year of Record was used to split sites into three main categories: current, historical, and unknown. Sites with at least one record dating from 1990 or after (through the present, 2021) were classified as current, while sites based on records dating from before 1990 were classified as historical. Year of Record was not known for all sites, and those without known dates were classified as unknown. Current and historical sites were also sub-divided by decade and C-SWG sampling period to further examine the distribution of sites and their land cover characteristics.

Of the 2,351 sites delineated, 78% were current, 14% were historical, and 8% were unknown (Table 8-1). Of the current sites delineated, 24% included records from the regional C-SWG sampling period (2018–2021; Table 8-1). Historical sites based on turtle records pre-dating 1970 accounted for 4% of all delineated sites (Table 8-1; Figure 8-1). In total, sites were delineated based on records from 86 of the past 171 years, with the most common year being 2019 when (6%) of sites were last observed (Figure 8-1). However, the plurality (23%) of total delineated sites dated from 2000–2009 (Table 8-1; Figure 8-1).

Table 8-1. Number and percent of total delineated Spotted Turtle sites by decade of most recent turtle record at the site. Site ranking classified sites based on records from before 1990 as historical, and those from 1990 or after as current. Year of record was not known for all sites (Unknown).

Site classification		Record decade	Number of sites	Percent of total sites
1857-1969		Pre-1970	83	4%
		1970–1979	71	3%
		1980–1989	166	7%
Total Historical			**320**	**14%**
		1990–1999	360	15%
		2000–2009	531	23%
2010-2021	Pre-C-SWG	2010–2017	498	21%
	C-SWG	2018–2021	449	19%
Total Current			**1,838**	**78%**
Unknown		Unknown	**193**	**8%**
Total			**2,351**	**100%**

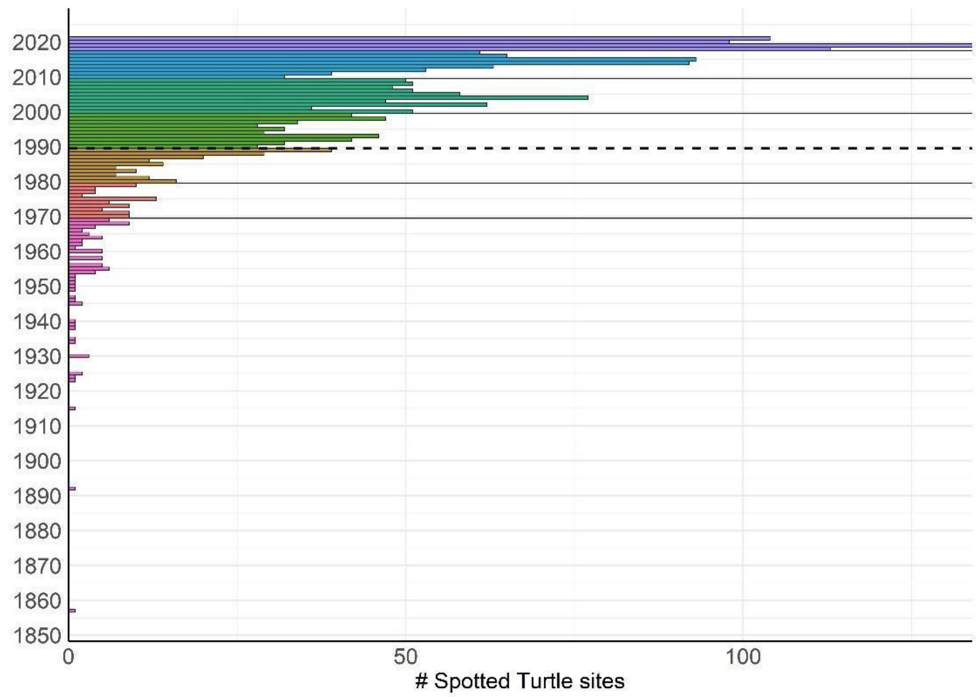


Figure 8-1. Number of delineated Spotted Turtle sites based on turtle records from the years 1850 to 2021. Solid lines and bar colors indicate decadal divides while the dashed line indicates the threshold between current vs historical sites.

Geographic Distribution of Sites

Current sites accounted for the majority of sites within each sub-region of the eastern United States and within each state except New York, which had more sites based on records from unknown years (Table 8-2). However, the distribution of historical and current sites varied across the region with the majority of historical sites occurring in the Southeast (Table 8-2; Figure 8-2) and the majority of current sites occurring in the Northeast (Table 8-2; Figure 8-2). The state with the most historical sites was North Carolina (n=96), followed closely by Massachusetts (n=92; Table 8-2; Figure 8-2). Both states had close to three times more historical sites than the next state (Georgia; n=32). Massachusetts also had the largest number of current sites (577; Table 8-2; Figure 8-2), accounting for over 30% of all current sites. It is important to note that the number of records within a state is a complex function of many factors, including: Spotted Turtle habitat suitability, survey effort and effort by the state to track the species (which partially depends on listing status), and fragmentation or human population density, which could increase the number of records since there are more people to report records and more roads on which to observe Spotted Turtles.

Table 8-2. The distribution (number of sites and associated percent of group total in the eastern United States) of historical (records from before 1990), current (records from 1990–2021), unknown (no record date available), and total delineated Spotted Turtle sites across states and their associated sub-regions on the East Coast.

Sub-region	State	Historical		Current		Unknown		Total	
		# Sites	% Total	# Sites	% Total	# Sites	% Total	# Sites	% Total
	CT	13	4.06	70	3.81	4	2.07	87	3.7
	MA	92	28.75	577	31.39	1	0.52	670	28.5
	ME	10	3.13	73	3.97	4	2.07	87	3.7
	NH	5	1.56	183	9.96	0	0	188	8
	RI	0	0	64	3.48	0	0	64	2.72
	VT	0	0	3	0.16	0	0	3	0.13
New England		**120**	**37.5**	**970**	**52.77**	**9**	**4.66**	**1,099**	**46.75**
	DC	0	0	1	0.05	0	0	1	0.04
	DE	1	0	47	2.56	2	1.04	50	2.13
	MD	0	0	48	2.61	0	0	48	2.04
	NJ	0	0	97	5.28	2	1.04	99	4.21
	NY	3	0.94	55	2.99	113	58.55	171	7.27
	PA	2	0.63	256	13.93	2	1.04	260	11.06
	VA	24	7.5	62	3.37	57	29.53	143	6.08
	WV	2	0.63	8	0.44	0	0	10	0.43
Mid-Atlantic		**32**	**10**	**574**	**31.23**	**176**	**91.19**	**782**	**33.26**
	FL	18	5.63	23	1.25	5	2.59	46	1.96
	GA	32	10	92	5.01	2	1.04	126	5.36
	NC	96	30	126	6.86	1	0.52	223	9.49
	SC	22	6.88	53	2.88	0	0	75	3.19
Southeast		**168**	**52.5**	**294**	**16**	**8**	**4.15**	**470**	**19.99**
Total (Eastern U.S.)		**320**	**100**	**1,838**	**100**	**193**	**100**	**2,351**	**100**

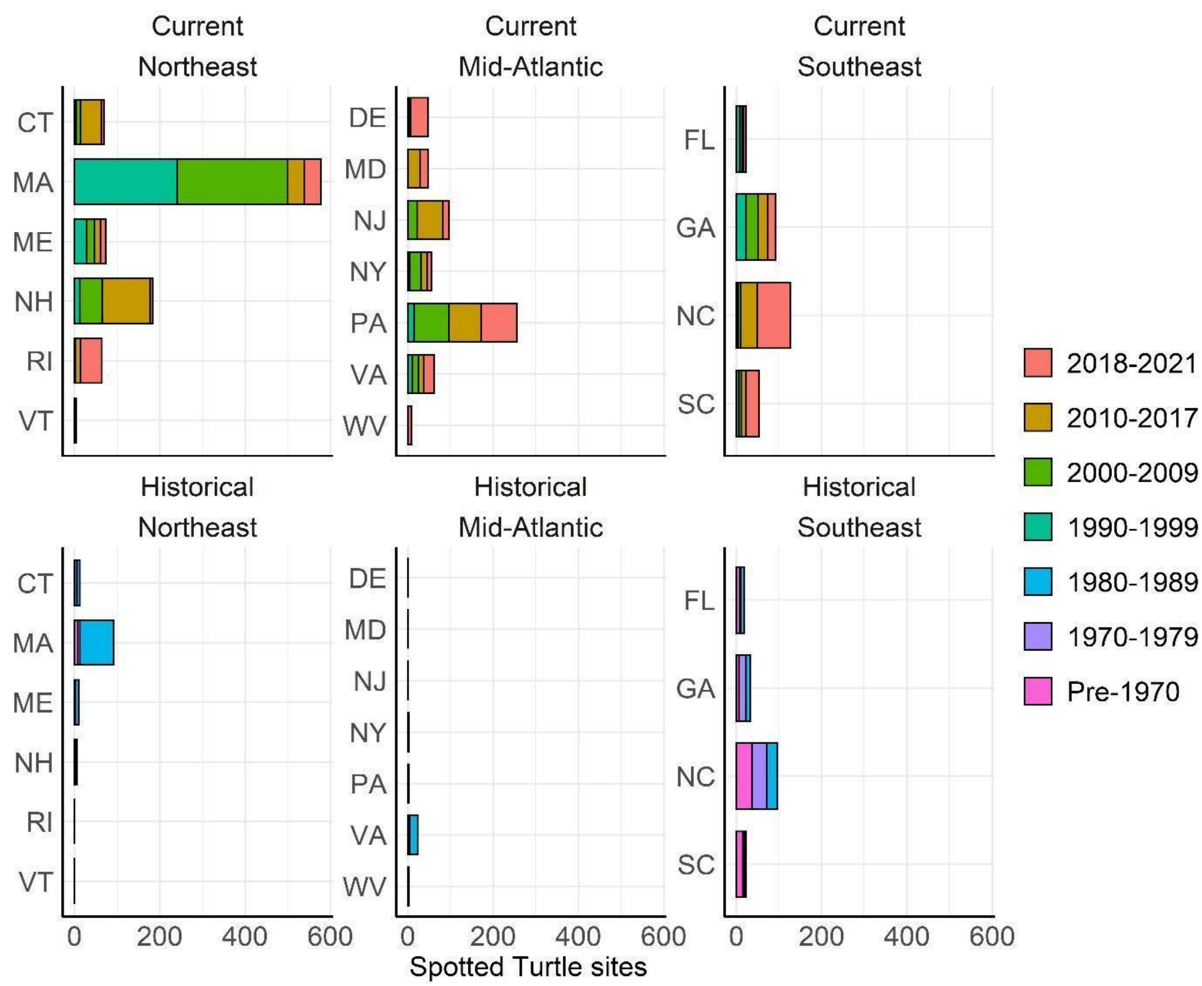


Figure 8-2. Distribution of current (top) and historical (bottom) Spotted Turtle sites within sub-regions (columns) and states (y-axis) of the eastern United States. Colors indicate the decade of most-recent Spotted Turtle record within sites.

Caveats

In the following analysis, historical sites were used to represent sites that may have low-density populations or populations that have become extirpated. This distinction allowed for a direct comparison between current "robust" populations and historical populations/sites and their associated habitat characteristics. However, because site classification (current or historical) was based solely on presence data, historical sites may also represent under-surveyed sites or even sites deemed "secure" that have not been prioritized for sampling.

To test whether sampling at a historical site was less likely to produce a Spotted Turtle capture than sampling at a current site, we removed all C-SWG sampling data from the records used to delineate sites and used the remaining most-recent record to determine the classification of Spotted Turtle sites. We then calculated how many current and historical sites were sampled, and at how many sites Spotted Turtles were captured. Of the 210 sites sampled during the regional C-SWG effort, captures were made at 172 sites and 107 of those sites had records pre-dating C-SWG sampling. Of these 107 sites, 99 were still classified as "current", while one was classified as "historical". Of the 38 sites surveyed without captures, three sites were historical and the other 35 were current (Figure 8-3). We then used these numbers in the Fisher's Exact test to determine whether we were significantly less likely to capture a Spotted Turtle at a historical site. Using this test, we did not find a significant difference in probability of captures between current and historical sites (p-value: 0.063; odds ratio: 0.12 [95% CI: 0.002, 1.155]). However, sample size for historical sites was very low (n=4), and it is therefore unsurprising that the confidence interval for odds ratios crossed one, indicating uncertainty and a lack of significance.

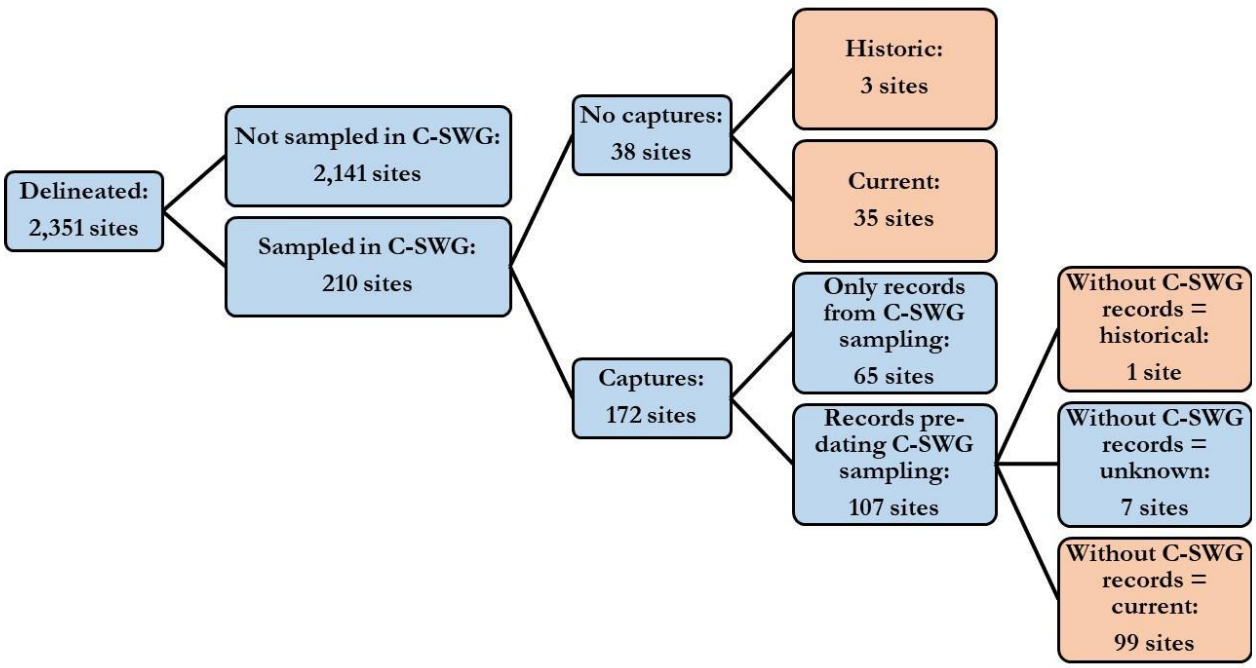


Figure 8-3. Breakdown of delineated Spotted Turtle sites by sampling success and classification. Pink boxes indicate the numbers used in the Fisher's Exact Test.

To further examine the relationship between sampling success and age of most-recent record (excluding the 2018–2021 C-SWG sampling effort), we also created a figure depicting the proportion of sampled sites that did and did not produce Spotted Turtle captures during the recent regional sampling effort, by decade and classification (Figure 8-4). While this does not demonstrate statistical significance, there does appear to be a clear relationship between year of most recent record and the likelihood of capturing Spotted Turtles. Nonetheless, without more current absence data, we do not know whether historical Spotted Turtle sites are accurate representatives of low-density or extirpated populations and conclusions should be interpreted with caution.

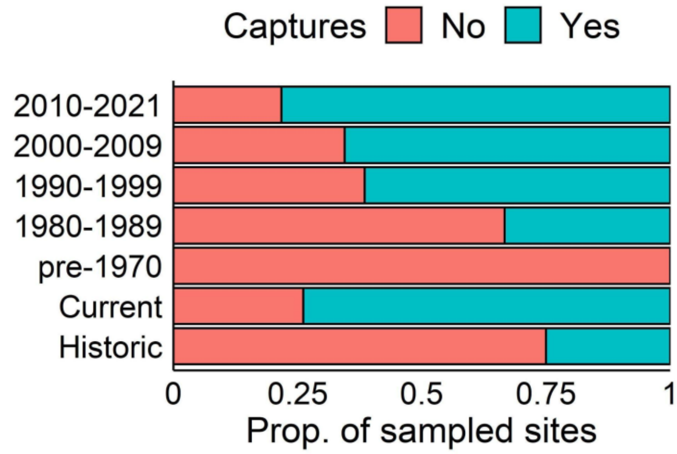


Figure 8-4. The proportion of sites at which Spotted Turtles were and were not captured during the 2018–2021 C-SWG sampling effort, by decade and site classification.

Spotted Turtle Site Attributes

Each Spotted Turtle site was attributed with data from four main attribute classes: Class I: Habitat abundance and quality; Class II: Within site fragmentation; Class III: Surrounding landscape context; and Class IV: Known Spotted Turtle population (Table 8-3). These attributes and their source data are further described in Part V of this document.

Assuming that historical sites, where no turtles have been documented in 30 years, might represent low density populations or those that have declined or become extirpated, we compared the mean value and standard error of 18 of these attributes between current and historical sites (Table 8-4) to assess the site characteristics that might be associated with population decline or extirpation. Three metrics based on C-SWG sampling in Class IV (catch per unit of effort [CPUE], age structure, and sex structure) were excluded from this analysis as they were not available across years.

Table 8-3. Four classes of attributes used to describe Spotted Turtle site characteristics. See Part V for additional details on source data.

Class I. Habitat abundance and quality	**Class II. Within site fragmentation**	**Class III. Surrounding landscape context (3km)**	**Class IV. Known Spotted Turtle population**
Area (km2): Total area within delineated site	**% Developed:** Percent of site that is high, medium, or low intensity development	**Dist. to site (km):** Distance to next nearest site	**# Records:** Total number of individual records used to delineate site
% Wetland: Percent of site that is covered by palustrine wetlands	**% Impervious:** Percent impervious surface cover within site	**% Forest (3km):** Percent of surrounding landscape that is forested	**Year of record:** Year of most recent turtle record used to delineate site
Wetland types: Wetland diversity within a site (count of palustrine types)	**% Road cover:** Percent of site covered by roads	**% Forest loss (3km):** Percent of surrounding landscape that experienced forest loss since 2000	**Excluded:** *CPUE* *Age structure* *Sex structure*
Models (combined): Habitat suitability models (2 models, scaled 0-1 and averaged)	**% Agriculture:** Percent of site cultivated for crops	**% Impervious (3km):** Percent impervious surface cover within the surrounding landscape	
	% Railroad: Percent of site covered by railroads	**% Agriculture (3km):** Percent of surrounding landscape cultivated for crops	
		% Road cover (3km): Percent of surrounding landscape covered by roads	
		Traffic/10^8 (3km): Traffic volume (divided by 10^8) in the surrounding landscape, based on major roads	

Current vs Historical Site Comparison

While current and historical Spotted Turtle sites did not differ in the amount of wetland or agricultural cover, historical sites had significantly higher percent road, developed, and impervious cover within sites compared to current sites (Table 8-4; Figure 8-5). Additionally, historical sites had significantly higher levels of forest loss within the surrounding landscape (Table 8-4; Figure 8-5) and were significantly farther from the next nearest Spotted Turtle site (Table 8-4; Figure 8-5). Conversely, current sites had significantly more forest cover in the surrounding landscape (Table 8-4; Figure 8-5), more wetland types within sites (Table 8-4; Figure 8-5), a higher number of Spotted Turtle records within sites (Table 8-4; Figure 8-5) and had higher habitat model scores (Table 8-4; Figure 8-5).

Table 8-4. Mean site attribute values and their standard errors (SE) for current sites (sites based on records from 1990 or later) and historical sites (based on records from before 1990). Attributes in bold and marked with * indicate the 95% confidence intervals of current and historical sites don't overlap.

Attribute	Current		Historical	
	Mean	SE	Mean	SE
% Agriculture	7.731	0.287	8.743	0.805
% Agriculture (3 km)	9.694	0.287	11.040	0.768
Area (in km2)	3.416	0.17	3.392	0.38
Year of record	2008.801	0.214	1974.809	0.923
% Developed*	**8.772**	**0.314**	**11.528**	**1.009**
Dist. to site (in km)*	**3.459**	**0.129**	**5.649**	**0.462**
% Forest (3 km)*	**43.182**	**0.485**	**34.996**	**1.090**
% Forest loss (3 km)*	**6.255**	**0.227**	**12.830**	**0.812**
% Impervious*	**15.639**	**0.408**	**19.579**	**1.323**
% Impervious (3 km)	19.021	0.402	19.407	1.189
# Records*	**6.207**	**0.487**	**1.225**	**0.052**
% Road cover*	**7.934**	**0.145**	**9.455**	**0.488**
% Road cover (3 km)	9.230	0.138	9.456	0.437
% Railroad	0.339	0.026	0.379	0.059
Models (combined)*	**0.229**	**0.003**	**0.192**	**0.007**
Traffic/10^8 (3 km)	4.08	0.135	3.88	0.328
% Wetland	20.182	0.436	19.882	1.116
Wetland types*	**9.192**	**0.185**	**6.781**	**0.340**

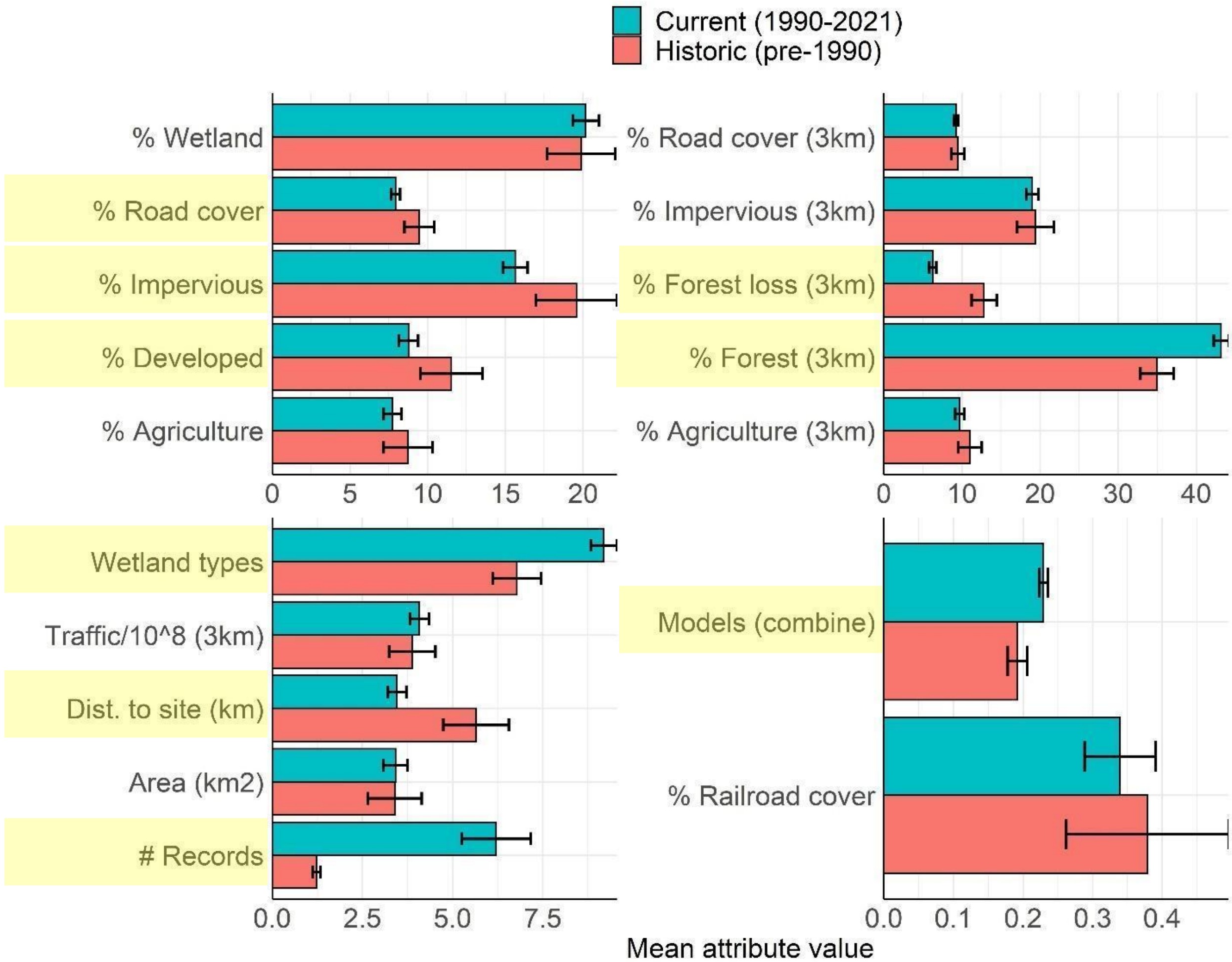


Figure 8-5. Mean site attribute values and 95% confidence intervals for current (records from 1990–2021) and historical (records from before 1990) Spotted Turtle sites. Attributes with significant differences between current and historical sites are highlighted. Scale varies by panel.

Unsurprisingly, several site attributes were highly correlated with one another (Table 8-5). Of the attributes that were significantly different between current and historical sites, percent developed, impervious, and road cover were correlated with one another as was wetland diversity (wetland types) and habitat models (Table 8-5).

The above analysis suggests that Spotted Turtle sites with only historical records are, on average, more urbanized and have less wetland diversity than sites with more current records. It also suggests that fragmentation at the local level (i.e., roads, development, and impervious surface) within the site may be more important than at the broader (3 km) scale; however, forest cover at that broad scale does appear important. While it is possible that some sites are categorized as historical because they have not been surveyed in that past 30 years, it is also possible that the populations at some of these historical Spotted Turtle sites are now less robust or extirpated due to changes in habitat quality.

Table 8-5. Pearson correlation coefficients for correlated (r ≥ 0.5) site attributes. Attributes that were significantly different between current and historical sites are in bold and marked with a *. Attributes from 2,156 sites were used to calculate coefficients (excluded sites with any unknown attributes).

Attribute 1	Attribute 2	Correlation Coefficient
% Agriculture	% Agriculture (3km)	0.76
% Developed*	**% Impervious***	0.96
	% Impervious (3km)	0.75
	% Road (3km)	0.72
	Traffic (3km)	0.54
% Impervious*	% Impervious (3km)	0.77
	% Road (3km)	0.75
	Traffic (3km)	0.54
% Impervious (3km)	% Road (3km)	0.96
	Traffic (3km)	0.77
% Road*	**% Developed***	0.83
	% Impervious*	0.88
	% Impervious (3km)	0.63
	% Road (3km)	0.67
% Road (3km)	Traffic (3km)	0.75
Habitat models*	% Wetland	0.74
	Wetland types*	0.63
Wetland types*	% Wetland	0.68
	Total area	0.62

Decade Comparison

To further examine the relationship between age of the most recent Spotted Turtle record and relative site quality, we repeated the above process using decade of record. Due to the low number of sites based on records from the late 1800s and early 1900s (Figure 8-1), all sites based on records pre-dating 1970 were grouped together (Table 8-1). We then grouped sites by decade from the 1970s through the 2000s, but the 2010s/2020s were split into pre-C-SWG sampling (2011–2017) and C-SWG sampling periods (2018–2021; Table 8-1) to balance the number of sites across groups, and to analyze sites sampled during the C-SWG project as a separate group.

While this was a region-wide (eastern United States) analysis, two states may have driven patterns seen within five of the seven decadal groupings examined. North Carolina accounted for 45% of sites based on turtle records from before 1970, and 48% of sites from the 1970s (Table 8-6; Figure 8-2); while Massachusetts accounted for 48% of sites based on records from the 1980s, 67% of sites from the 1990s, and 49% of sites from the 2000s (Table 8-6; Figure 8-2). Therefore, statistical differences between decadal groupings were not emphasized and overall patterns over time were instead emphasized.

Table 8-6. Count of delineated Spotted Turtle sites by state and decade, with the 2010s and 2020s, grouped by time of C-SWG sampling rather than along decadal lines. Values that are bold and marked with a * represent decades in which a single state accounted for at least 50% of sites within that decade.

State	Pre-1970	1970–1979	1980–1989	1990–1999	2000–2009	2010–2017	2018–2021	Unknown	Total
CT	1	4	8	3	11	49	7	4	**87**
DC	0	0	0	0	0	0	1	0	**1**
DE	0	1	0	0	3	4	40	2	**50**
FL	8	2	8	9	4	4	6	5	**46**
GA	7	15	10	23	27	23	19	2	**126**
MA	7	6	**79***	**241***	**258***	39	39	1	**670**
MD	0	0	0	0	1	27	20	0	**48**
ME	2	0	8	28	19	14	12	4	**87**
NC	**37***	**34***	25	4	6	39	77	1	**223**
NH	1	1	3	13	52	112	6	0	**188**
NJ	0	0	0	1	21	60	15	2	**99**
NY	1	1	1	5	26	14	10	113	**171**
PA	0	0	2	15	81	75	85	2	**260**
RI	0	0	0	2	0	12	50	0	**64**
SC	15	4	3	6	5	12	30	0	**75**
VA	2	3	19	10	15	13	24	57	**143**
VT	0	0	0	0	1	1	1	0	**3**
WV	2	0	0	0	1	0	7	0	**10**
Eastern U.S.	**83**	**71**	**166**	**360**	**531**	**498**	**449**	**193**	**2,351**

Sites where Spotted Turtles have been observed most recently (2018–2021) have the least amount of road cover, impervious surface, and developed land, and the greatest amount of wetland cover compared to sites where turtles were observed longer ago and not again more recently (Figure 8-6). Sites with a last observation in the 1990s appear to have the least amount of wetland cover, most road cover, most impervious surface cover, and greatest developed area (though not significantly more than sites observed in the 1980s or before 1970).

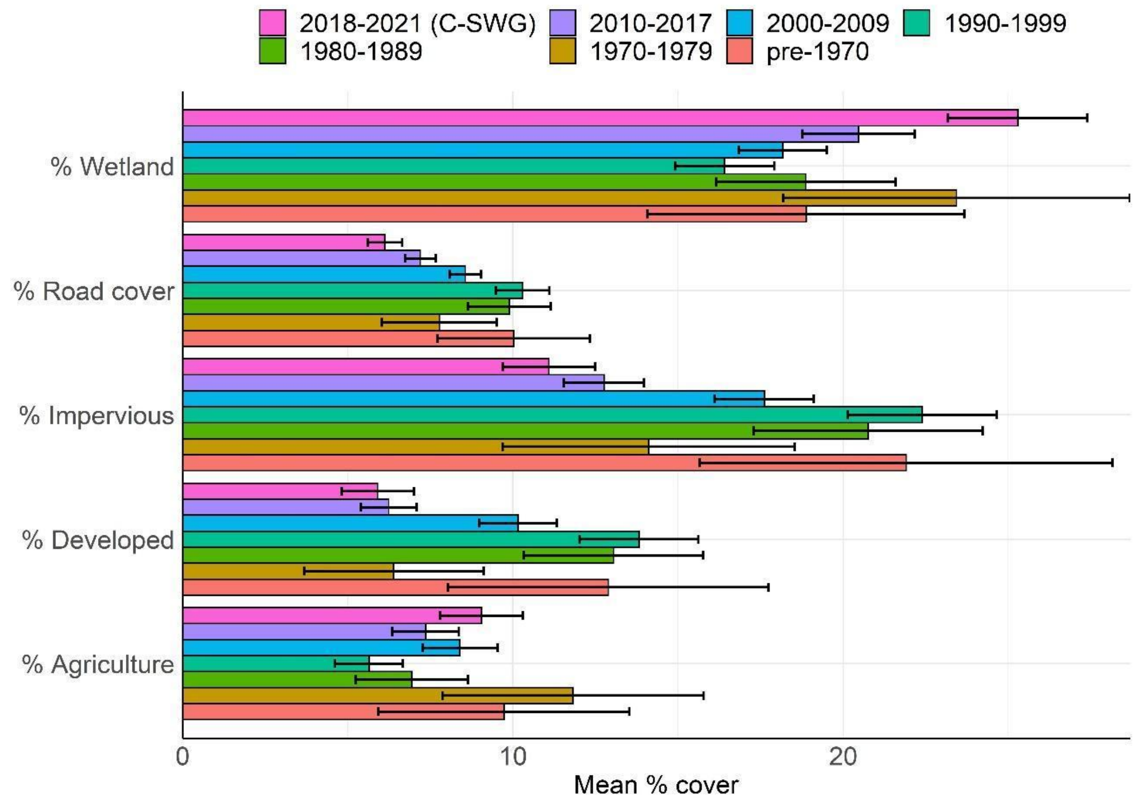


Figure 8-6. Mean percent cover and 95% confidence intervals for within-site attributes at delineated Spotted Turtle sites, grouped by decade.

At the landscape (3 km) scale, sites with more recent observations have greater forest cover, with the exception of sites sampled during the C-SWG effort (Figure 8-7), again suggesting that populations with less forest cover may have experienced decline or extirpation such that Spotted Turtles can no longer be documented there.

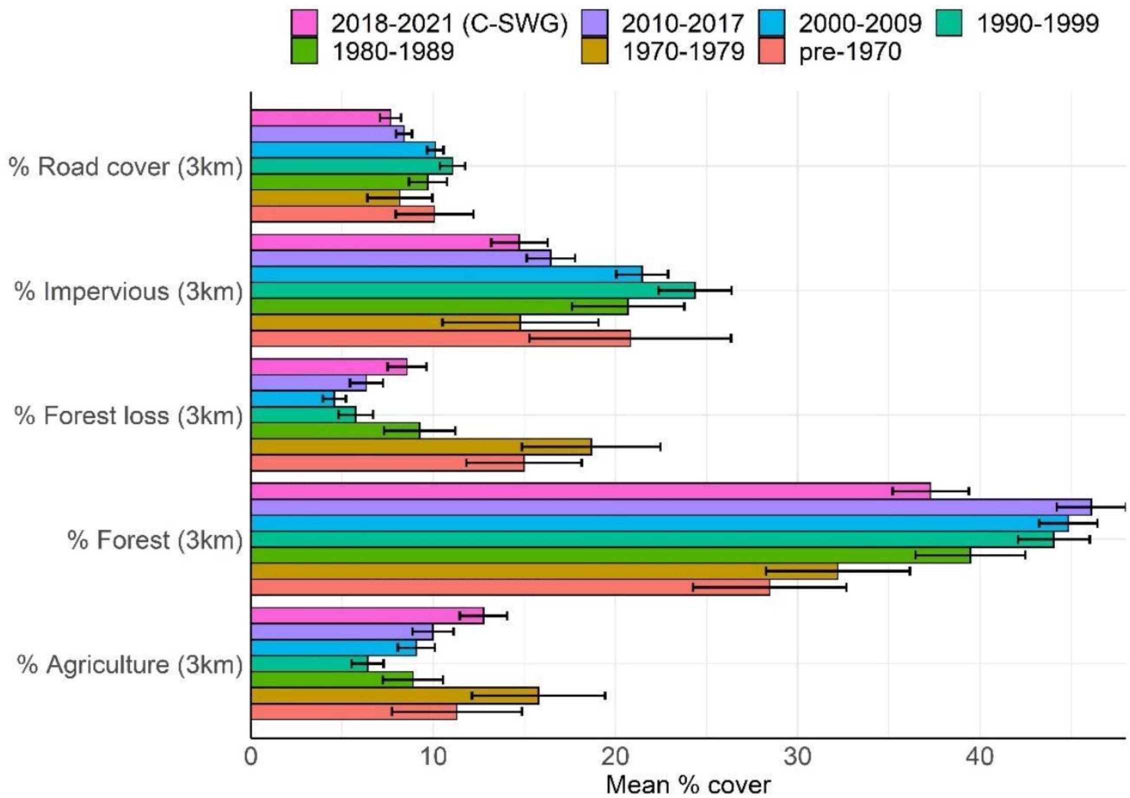


Figure 8-7. Mean percent cover and 95% confidence intervals for landscape attributes (3km buffer of sites) at delineated Spotted Turtle sites, grouped by decade.

Sites with more recent observations have a greater number of palustrine wetland types and number of turtle records within a site, with significantly more records at sites observed since 2000, and a large increase in records correlated with the C-SWG sampling effort (Figure 8-8). Mean site area appears consistent regardless of Year of Record, until the C-SWG sampling period, with the most recent sites being larger (Table 8-6; Figure 8-8), possibly from increased sampling effort. It is probable that the trapping protocol followed by partners regionally influenced site delineation by sampling multiple nearby wetlands, resulting in larger overall sites.

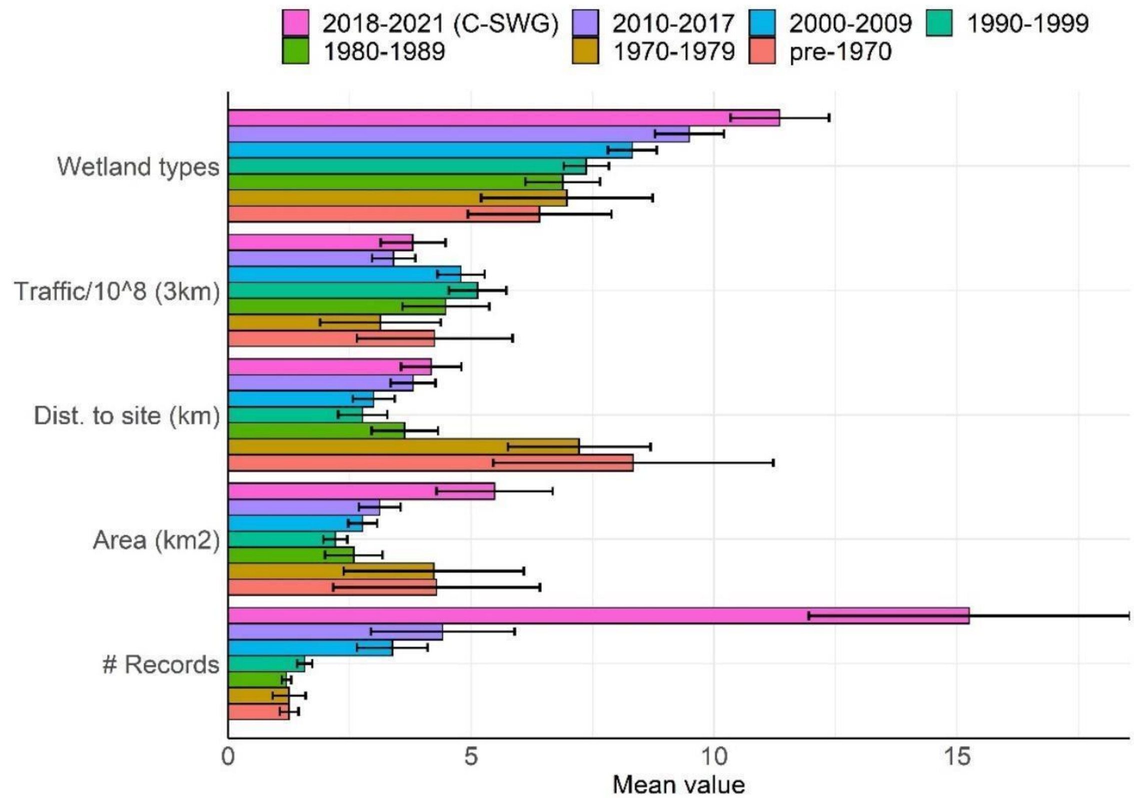


Figure 8-8. Mean value and 95% confidence intervals for attributes at delineated Spotted Turtle sites, grouped by decade.

Protected Status

To assess the potential for future land-use change within Spotted Turtles sites, we evaluated protected status of delineated sites in the eastern United States. We used the USGS Protected Areas Database of the United States (PAD-US) 2.1 (USGS GAP 2020) to calculate the area within each of the 2,351 delineated Spotted Turtle sites with GAP status levels 1–3:

GAP 1: Areas that are permanently protected from conversion of natural land cover with a mandated management plan within which disturbance events proceed or are mimicked (managed for biodiversity).

GAP 2: Areas that are permanently protected from conversion of natural land cover with a mandated management plan within which disturbance events can be suppressed (managed for biodiversity).

GAP 3: Areas where the majority of the land is permanently protected from conversion of natural land cover but are subject to extractive uses of either a broad, low-intensity type (e.g., logging, Off Highway Vehicle recreation) or localized intense type (e.g., mining). Protection for federally listed endangered and threatened species is granted throughout the area (managed for multiple uses).

We did not include sites with GAP 4 classification because there is no known biodiversity protection at these sites.

Approximately 28% of the total area within Spotted Turtle sites region-wide has some level of protection (GAP status 1, 2, or 3), while 15.1% of the 2,351 delineated sites are more than 50% protected using this designation. Approximately 31% of all delineated habitat within current sites is protected, while 17% of delineated habitat within historical sites is protected (Table 8-7).

Table 8-7. Percent of delineated sites and habitat (hectares) across the region that are protected (GAP levels 1-3) by decade of most recent record within each site and associated site classification (historical versus current). The percent of sites that are at least 50% protected is also indicated. Sites based on records of unknown age are excluded.

		Delineated		Percent		
Site classification	**Decade**	**Sites**	**Hectares**	**Hectares protected**	**Sites with any protection**	**Sites ≥50% protected**
Historical	Pre-1970	83	35,591.93	17.62%	44.58%	10.84%
	1970-1979	71	30,045.28	23.76%	38.03%	8.45%
	1980-1989	166	42,901.58	12.61%	58.43%	10.84%
Historical total		**320**	**108,538.79**	**17.34%**	**50.31%**	**10.31%**
Current	1990-1999	360	79,405.69	15.04%	63.61%	7.50%
	2000-2009	531	146,864.32	23.51%	66.67%	11.86%
	2010-2017	498	155,322.44	26.10%	67.47%	17.67%
	2018-2021	449	246,202.24	44.01%	64.14%	28.95%
Current total		**1,838**	**627,794.69**	**31.12%**	**65.67%**	**16.76%**

The mean percent of protected habitat within delineated sites was not significantly different across site classification or decade of most recent record except for sites sampled during the 2018−2021 C-SWG population assessment (Figure 8-9). It is probable that sampling effort was concentrated in federal and state lands so site selection for the population assessment may be the driving force behind this pattern.

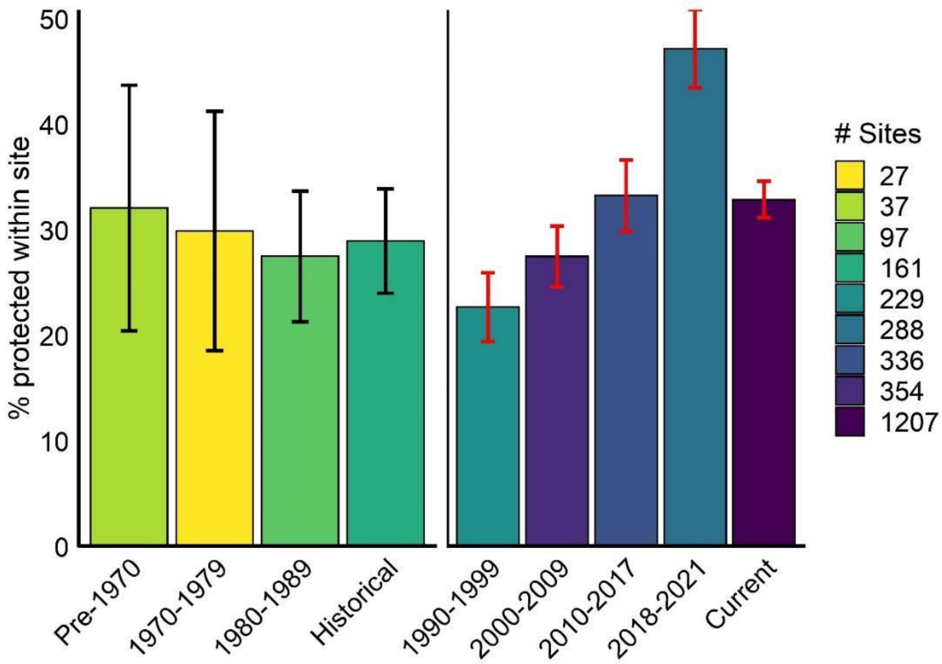


Figure 8-9. The mean percent of delineated habitat that is protected within Spotted Turtle sites by decade of most recent record and associated site classification. Color indicates the number of sites averaged by category, and 95% confidence intervals are shown.

The amount of habitat protected within current and historical sites varies by state (Figure 8-10). While the proportion of delineated historical sites and hectares protected is higher than that for current sites in some states, overall, the percent of protected habitat within current sites tends to be higher (Figure 8-10).

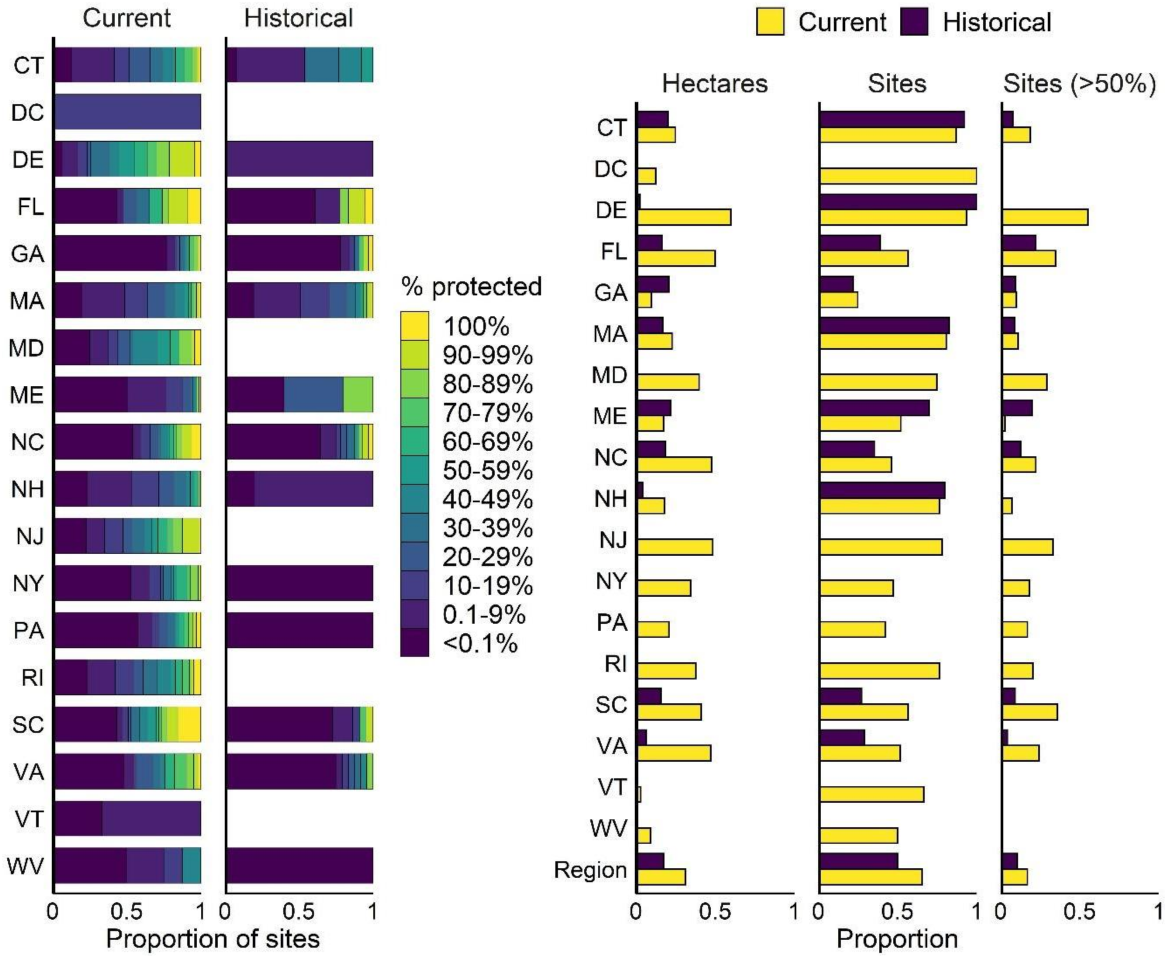


Figure 8-10. A) Proportion of delineated Spotted Turtle sites with <0.1−100% of delineated area protected (GAP status 1, 2, 3), by state and site classification (left) and B) the proportion of delineated hectares and sites that are protected by state and site classification. Proportion of sites with at least 50% protection is also provided (right).

Conclusions

Overall, it appears that sites with more recent observations have less urbanization within them and greater forest in the surrounding landscape than sites where Spotted Turtles were documented historically, but not in recent years, suggesting that populations at more urbanized sites may have declined or become extirpated. However, concerted sampling effort at historical sites would be necessary to confirm absence and habitat suitability at these sites as lack of a recent record may simply indicate a lack of survey effort or observation tracking. In fact, some historical sites may not have been revisited recently because they are deemed secure. This may be particularly true in North Carolina, where tracking the species may not be a priority due to its widespread distribution in the state, and the large number of historical records there likely reflects a lack of search effort and record tracking, rather than habitat loss or decline.

Chapter 9. Wetland Loss

Jessica R. Meck, Eric B. Liebgold, and Thomas S.B. Akre

Introduction

Freshwater wetlands are considered one of the most valuable, biodiverse ecosystems on Earth, supporting hotspots of richness and diversity across diverse lineages and taxonomic clades and providing measurable and critical ecosystem services. Freshwater ecosystems host approximately 100,000 known species across all taxa globally (World Wildlife Fund 2016). Freshwater wetlands are notable for their role in mitigating severe flooding, protecting shorelines during extreme weather and tidal events (Mitsch and Gosselink 2015), and filtering polluted waters. Humans further benefit from wetland ecosystem services ranging from food, water, and timber to air quality, climate, and disease regulation (Mitsch and Gosselink 2015). Wetlands are also often heavily used by people for recreation opportunities such as boating, swimming, hunting, and wildlife observation.

Historically since European colonization in the 1600s, wetlands in the United States have been targeted for drainage, filling, and development. In general, since the Clean Water Act of 1972 and similar/subsequent state statutes, there has been greater protection and restoration of wetlands in the United States. Reduced area of wetland habitats results in a lower carrying capacity for Spotted Turtles and other wetland dependent species, and loss and fragmentation of wetlands can reduce the function, diversity, and integrity of those that remain. Spotted Turtles' primary extent of occurrence is along the Atlantic Coastal Plain of the eastern United States, the region with the longest history of wetland loss. This Chapter provides an overview of historical wetland loss in the United States, its relevance to Spotted Turtles, and implications for future conservation efforts.

Historical Wetland Loss and Modification

The United States has a long history of systematic wetland draining and filling that primarily began with European colonization in the 1600s. During colonial settlement, wetlands were considered impediments to travel and reservoirs of disease, thus they were targeted for reclamation for agriculture and development (Dahl and Allord 1996). As the country developed and expanded westward, legislation was passed in the 1800s that promoted wetland conversion and agriculture operations. Notably, the Swamp Land Acts of 1849, 1850, 1860 provided federal funding to states to drain wetlands that would increase the land's value. The total land claimed by states was 82,126,348 acres, half of which was claimed by only three states: Florida, Arkansas, and Louisiana. The United States government determined that 77,000,000 acres were drainable and if completed and divided into 40-acre farms, the land could house 1,925,000 families, a testament to population growth at the time (Wright 1907). It wasn't until 1934 that the first legislation was passed that promoted the acquisition and restoration of wetlands, The Migratory Bird Hunting Stamp Act and the Fish and Wildlife Coordination Act (Dahl and Allord 1996).

It has been estimated that overall, the United States lost half (53%) of its wetlands between the 1780s to 1980s (Dahl 1990). The U.S. Fish and Wildlife Service began monitoring the status and trends of the nation's wetlands in 1974 with the development of the National Wetland Inventory (NWI) Program. The reports produced from the NWI Program since the 1970s have concluded that wetland loss still continues at a rate of tens of thousands of acres annually despite the legislation and conservation efforts that have been implemented. The rate of wetland loss has decreased over time, however, from an average net loss of 458,000 acres/year between the 1950s to 1970s, to 13,800 acres/year between 2004 to 2009 (Frayer et al. 1983; Dahl 2011; Figure 9-1). The only period where the nation saw a net gain of wetlands was between 1998 and 2004 (Dahl 2006), though this was largely due to freshwater pond development, which is not an optimal habitat for Spotted Turtles. However, during that same time period, the coastal watersheds of the eastern United States continued to lose 60,047 acres/year (Dahl 2006; Stedman and Dahl 2008).

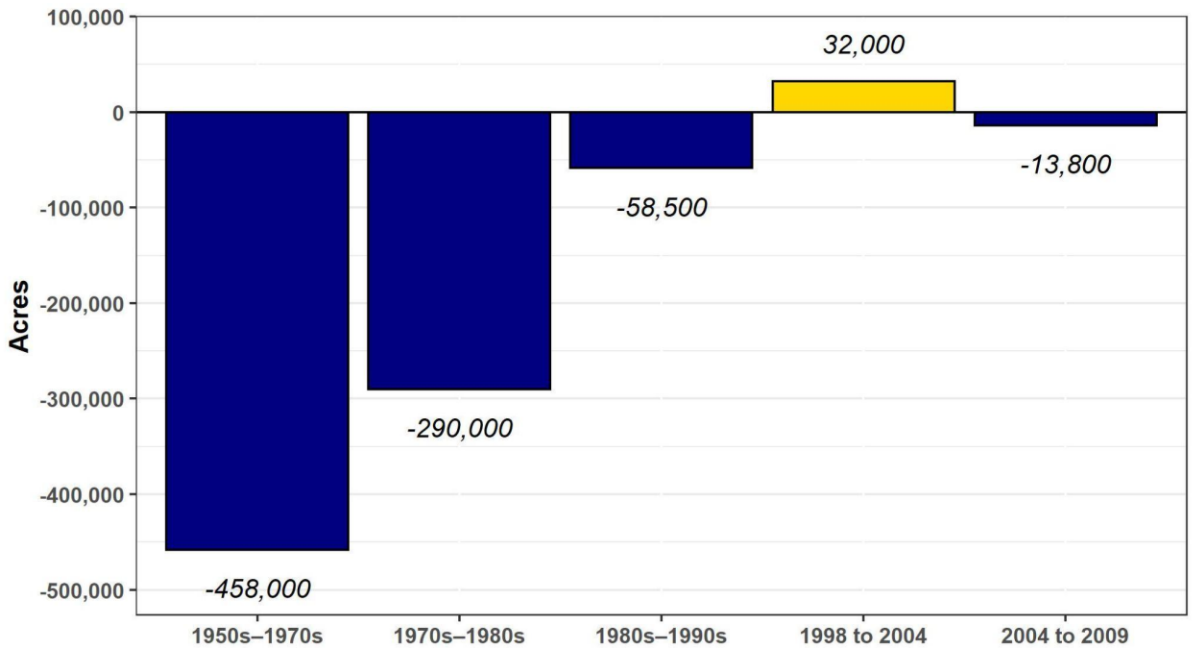


Figure 9-1: The average annual net loss and gain estimates of wetlands in the continental United States from 1954 to 2009. Adapted from Dahl 2011 (Figure 19). Sources: Frayer et al. 1983; Dahl and Johnson 1991; Dahl 2000, 2006, 2011.

Freshwater vegetated wetlands (i.e., palustrine forested, emergent, and scrub wetlands) have been the most impacted given that they are the most abundant and thus, often come into conflict with competing land and development interests (Dahl 2011). The national trends of all wetland types have shown a decreasing rate of loss from 334,400 acres/year between 1974 and 1984 to 41,200 acres/year between 2004 and 2009 (Dahl and Johnson 1991; Dahl 2011; Figure 9-2). The NWI reports also indicate that the majority of any net gain in the freshwater category is accounted for by ponds developed via commercial development or agriculture, while vegetated wetlands have continued to decline (Frayer et al. 1983; Dahl and Johnson 1991; Dahl 2000, 2006, 2011). These trends and changes indicate that the overall quantity and quality of freshwater wetlands in the United States have only declined despite having state and national legislation enacted to protect them.

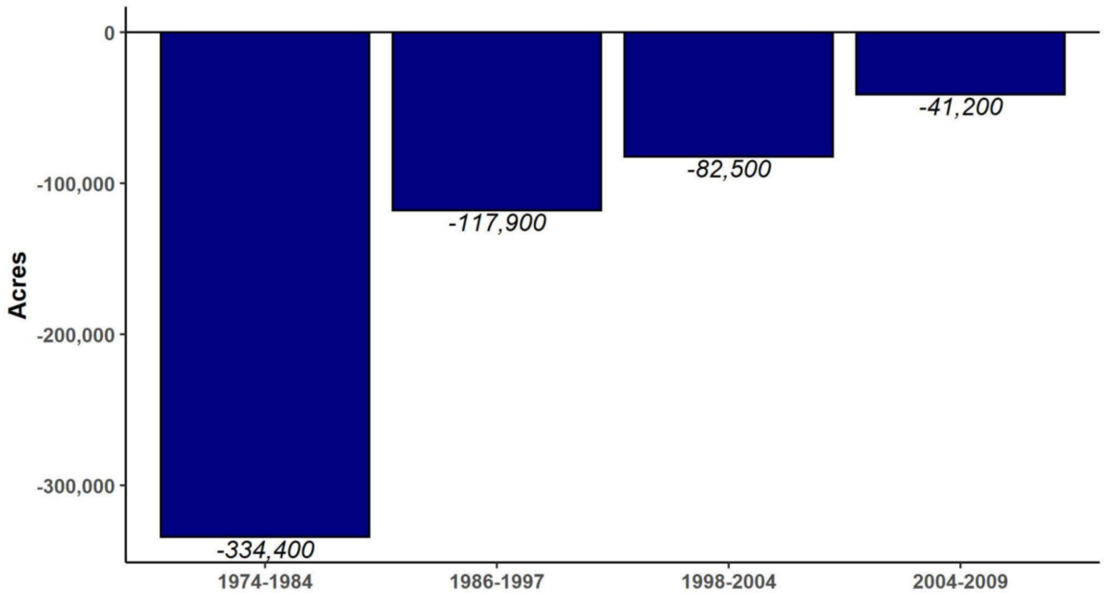


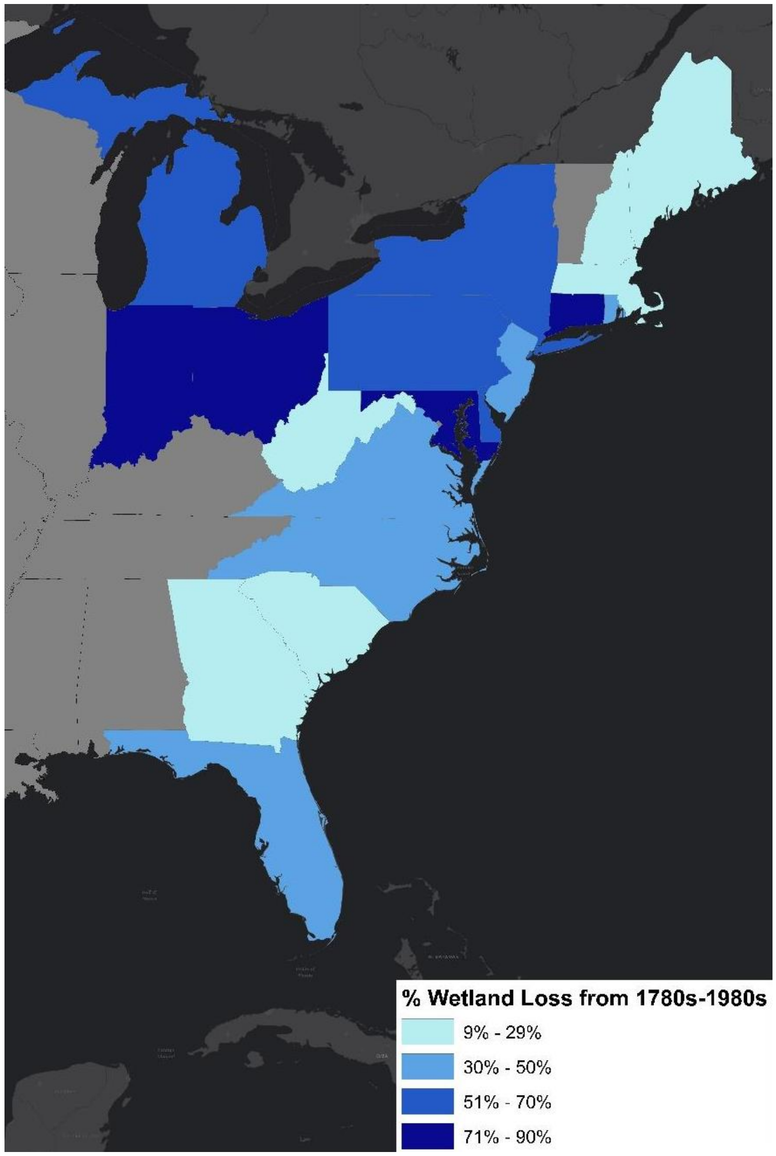
Figure 9-2: Estimated average annual net loss of vegetated freshwater wetlands (i.e., palustrine forested, palustrine shrub and palustrine emergent wetlands) in the continental United States from 1974 to 2009. Adapted from Dahl 2011 (Figure 20). Sources: Dahl and Johnson 1991, Dahl 2000; 2006; 2011.

Relevance to Spotted Turtles

The effect of large-scale wetland loss and conversion on Spotted Turtles has probably been net negative. States with Spotted Turtle populations averaged a 47% loss of historical wetlands between the 1780s and 1980s (Map 9-1; Dahl 1990). While we do not know the true extent of the Spotted Turtle's historical range and distribution prior to European settlement, it is likely they were once more widely distributed across many states where their range is currently restricted by development and wetland loss, and therefore the 47% estimate may be a reasonable approximation of direct loss of habitat and loss of connectivity between populations; however, this includes all wetland types not only those that support Spotted Turtles.

Two examples of large-scale wetland loss in the Spotted Turtle range include the Great Dismal Swamp in Virginia and North Carolina and the Black Swamp in northwestern Ohio (Dahl and Allord 1996; DSCWC 2017; Mitsch 2017). Both wetlands had extensive timber harvesting and ditching occur for the purpose of agriculture. The Black Swamp consisted of 3,072,000 acres of elm-ash forested wetland (approximately the size of Connecticut) that was completely harvested by the 19th century. The true impact on the freshwater species, including Spotted Turtles, is unknown, but the landscape continues to be negatively impacted by yearly algae blooms from the surrounding agricultural operations (Mitsch 2017). The Great Dismal Swamp is now a National Wildlife Refuge and Spotted Turtles continue to occur there; however, the impacts of ditching on the historic population size are unknown.

Throughout the Spotted Turtle range, the species uses a variety of habitat types. In the Mid-Atlantic region, they use tussock sedge wetlands, among other types of habitats, particularly for nesting. Geomorphologic research in the Piedmont River Valley in Pennsylvania and Maryland indicates a dramatic decrease in tussock sedge wetlands in this valley shortly after the start of the industrial age. Sediment core analysis shows that these habitats were very stable from 4300 yr BP to ca. A.D 1775, despite natural disturbances such as droughts, major storm events, fire, beaver activity, as well as anthropogenic disturbances at that time. These wetlands changed dramatically between A.D. 1775 and 1835 due to dams and the accumulation of legacy sediment, silt and clay originating from land clearing and breaching of dams (Hilgartner et al. 2011). Such localized changes may not be direct loss, though they may negatively influence Spotted Turtle populations, and therefore may be above and beyond loss estimated by Dahl (1990). However, it is important to note that Spotted Turtles also utilize anthropogenic ditches throughout their range and therefore some anthropogenic wetland change may, in fact, provide suitable habitat or even improve habitat quality in some circumstances.



Map 9-1: The estimated percent loss of wetlands for states with Spotted Turtles between the 1780s and 1980s (source: Dahl 1990). One state that has noted a discrepancy with these estimates from Dahl (1990) was Connecticut. Connecticut Department of Energy and Environmental Protection (DEEP) estimated between 30%–50% wetland loss (Metzler and Tiner 1992). Vermont and Illinois were excluded due to their low numbers of Spotted Turtle populations and their status at the edge of the species range.

Recent Trends in Spotted Turtle Habitat

Within the past few decades, numerous status and trend reports have documented wetland loss more relevant to Spotted Turtle populations. After the NWI program was established, studies at various spatial scales (e.g., statewide, county, or watershed) were conducted to assess wetland trends. At least 22 NWI reports were found to be within the current Spotted Turtle range and specifically reported changes to three categories of vegetated palustrine wetlands: forested wetlands, scrub-shrub wetlands and emergent wetlands (hereafter referred to as vegetated palustrine wetlands). These three categories were selected to best represent Spotted Turtle habitat broadly and for consistency in methods for defining Spotted Turtle habitat in this status assessment (see Chapter 2). Based on these reports, an estimated 179,500 acres of vegetated palustrine wetlands were lost between the 1950s and mid-2000s (Table 9-1). While these categories best represent Spotted Turtle habitat, they do not necessarily represent Spotted Turtle populations. Furthermore, the methods among the reports varied and do not incorporate smaller, isolated wetlands, like vernal pools, that are not included in the NWI. In addition, these reports represent only 12 of 21 states with Spotted Turtles at varying spatial scales, suggesting that the actual estimate of habitat loss for Spotted Turtles may be much higher.

An additional study by Carle (2011) evaluated wetland loss and gains in coastal North Carolina, a regionally significant state for Spotted Turtles due to widespread distribution and large population sizes (see Part III). Between the years 1994 and 2001, it was estimated that of the 20 counties evaluated, a total of 62,525 acres (or 1.95% wetland area) was lost to development or converted to open water. It was noted that estuarine wetlands are well protected by state law and experienced relatively little loss, while non-tidal freshwater wetlands suffered the most loss despite state and federal laws regulating wetland impacts (Carle 2011). The total loss estimate was also three times larger than the amount of wetland mitigation performed in the study's counties and time period (Carle 2011).

Table 9-1. Summary of the 22 wetland status and trends reports potentially relevant to the Spotted Turtle and its associated palustrine wetland habitat. The "Palustrine Acres Lost" refers to the net loss of vegetated palustrine wetlands (i.e., forested wetlands, scrub-shrub wetlands, and emergent wetlands) during the study period.

State	Time Period	Primary Study Area	Palustrine Acres Lost	Source
Maine	1970s – 1980s	Casco Bay Estuary	228	Foulis and Tiner 1994*b*
Maine New Hampshire Massachusetts	1977 – 1986	Gulf of Maine	282	Foulis et al. 1994*d*
Massachusetts	1977 – 1991	Neponset Watershed	92	Tiner et al. 1998
Massachusetts	1977 – 1986	Plum Island to Scituate	164	Foulis and Tiner 1994*c*
Massachusetts	1977 – 1986	Plymouth County	1,245	Tiner and Zinni 1988
Massachusetts	1990 – 2005	Statewide	12,860	Rhodes et al. 2019
Connecticut	1990 – 2010	Statewide	273	Tiner et al. 2013
New York	1968 – 1984	Croton Watershed	146	Tiner et al. 1999
New York	1984 – 1994	Croton Watershed	43	Tiner et al. 1999
New Jersey	1977 – 1984	Cape May County	257	Smith and Tiner 1993
New Jersey	1984 – 1991	Cape May County	238	Smith and Tiner 1993
New Jersey	1950s – 1960s	Hackensack Meadowlands	2,760	Tiner et al. 2002
New Jersey	1966 – 1985	Hackensack Meadowlands	4,870	Tiner et al. 2002
Pennsylvania	1956 – 1979	Statewide	28,000	Tiner 1990
Delaware	1981 – 1992	Statewide	1,894	Tiner 2001
Delaware	1992 – 2007	Statewide	3,126	Tiner et al. 2011
Maryland	1981 – 1990	Anne Arundel County	153	Tiner and Foulis 1992*a*
Maryland	1981 – 1989	Prince George's County	229	Tiner and Foulis 1992*b*
Maryland	1981 – 1989	Dorchester County	988	Tiner and Foulis 1994*a*
Maryland	1981 – 1989	Calvert County	74	Tiner and Foulis 1994*b*
Maryland	1981 – 1989	Charles County	163	Tiner and Foulis 1994*c*
Maryland	1981 – 1989	St. Mary's County	143	Foulis and Tiner 1994*a*
Virginia	1994 – 2000	Southeast Virginia	2,545	Tiner et al. 2005
South Carolina	1982 – 1989	Statewide	18,800	Dahl 1999
Georgia	1970s – 1980s	Statewide	100,000	Dahl and Johnson 1991
Total States: 12	**Date Range: 1950 – 2010**		**Acres: 179,573**	**Reports: 22**

Future Directions

Many important wetland types for Spotted Turtles, including vernal pools and ditches, are difficult to map and are not included in NWI assessments, therefore the true extent of loss of Spotted Turtle habitat is unknown. In addition, the broad wetland classes assessed here include many unsuitable habitats as well, and the suitability of wetland types varies throughout the species' range. A comprehensive analysis should be conducted to evaluate the historical wetland loss specific to

Spotted Turtles to better understand the extent of habitat degradation. Future conservation efforts should focus on maintaining and restoring vegetated palustrine wetlands that would benefit the Spotted Turtle and other associated species.

Chapter 10. Projected Effects of Climate Change in Spotted Turtle Habitat

H. Patrick Roberts and Cullen M. Mackenzie

Introduction

As noted in Appendix 1-A, climate factors and climate change were identified by experts as potential threats to Spotted Turtle populations. Climate change is expected to drive a global reconfiguration of species distributions, with suitable climatic conditions for temperate species generally shifting poleward, but species-specific variation exists in response to climate change due to differences in internal and external factors that drive distributions (Chen et al. 2011). With rapid niche evolution unlikely (Quintero and Wiens 2013), long-term survival of species experiencing extensive range shifts may ultimately depend in part upon their capacity to spatially track such changes (Loarie et al. 2009). Efforts to elucidate how species distributions may shift under future climate scenarios provide an understanding of the relative threat of climate change among species, as well as a means by which to guide and prioritize conservation actions.

In this Chapter we used two approaches to assess the magnitude of change of projected climate conditions within the species range. Specific objectives were to (1) model the current species distribution using climate data and estimate change in that distribution using future climate projections, and (2) estimate the potential for climate change to affect known, delineated Spotted Turtle sites throughout the eastern United States. It is important to note that the mechanisms by which populations might change (through increases or decreases in recruitment or mortality) are not explicitly considered as part of this analysis, rather our objectives were to assess the potential magnitude of the environmental change only.

Methods

Distribution Modeling

Study Area.—The study area for the modeled habitat encompassed the known extent of the Spotted Turtle species range as well as more distant areas where Spotted Turtles could potentially disperse (Merow et al. 2014) or assisted migration could potentially occur (McLachlan et al. 2007; Hallfors et al. 2016), which we defined as all land area within 500 km of occurrence locations. While the focus of this Plan is the eastern United States, utilizing the entire range of the species allowed us to investigate the potential for local adaptation, and see how different regions might respond differently to climate change.

Species Occurrence Data.—We gathered species occurrence information from two primary sources: the database consisting of state agency occurrence records, museum collections, non-profit databases, and personal datasets described in Chapter 2 and the Global Biodiversity Information Facility (GBIF.org). We used GBIF records for the western portion of the species range from Illinois to western New York and southern Canada. To minimize sampling bias, we randomly selected as many records as possible while maintaining a minimum distance of 20 km between all records using ArcGIS 10.5 (Environmental Systems Research Institute, Inc., Redlands, CA). We chose 20 km because it was similar to the typical distance between records in the western portion of the range.

Climate Data.—We considered 19 bioclimatic variables provided by the WorldClim dataset (www.worldclim.org; Fick and Hijmans 2017) for modeling historical (1970–2000) and future (2081–2100) distributions. Due to uncertainty and variation among models, we considered eight different global climate models for projecting suitable conditions into the future: a Beijing Climate Center Climate System Model (BCC-CSM2-MR), two National Center for Meteorological Research models (CNRM-CM6-1 and CNRM-ESM2-1), Canadian Earth System Model version 5 (CanESM5), an Institut Pierre Simon Laplace model (IPSL-CM6A-LR), the Model for Interdisciplinary Research on Climate, Earth System version 2 for Long-term simulations (MIROC-ES2L), Model for Interdisciplinary Research on Climate model version 6 (MIROC6), and the Meteorological Research Institute Earth System Model Version 2.0 (MRI-ESM2-0). For each global climate model, we considered two Shared Socioeconomic Pathways reflecting intermediate (SSP2-4.5) and extreme (SSP5-8.5) emissions/warming scenarios for the future temporal window from 2081 to 2100. We used spatial resolutions of 30 seconds and 2.5 minutes (lowest available) for current and future climate data respectively.

Species Distribution Models.—Due to a lack of true absence data, we used ArcGIS to randomly generate pseudo-absences within the respective focal areas (i.e., a 500 km buffer) for each analysis at approximately 10:1 pseudo-absence-to-presence ratio. Because we had no prior evidence or expectations about which climate variables would influence each population's distribution, we considered all 19 bioclimatic variables for inclusion in species distribution models. To select variables that would be considered in the final model, we first created two univariate logistic regression models for each bioclimatic variable with presence/pseudo-absence as the response variable: one containing a linear term and the other containing a quadratic term. Next, for each variable combination with $r > 0.6$, we excluded the variable that performed worse with respect to its Akaike's Information Criterion (AIC) value. Last, for each bioclimatic variable remaining, we selected the model (linear or quadratic) with the best (i.e., lowest) AIC value.

We used an ensemble modeling approach to produce species distribution models, which estimates the likelihood of species presence using multiple modeling techniques. We used default settings in the "BIOMOD2" package (Thuiller et al. 2016) in R to create all ensemble models. Four types of models contributed to each ensemble, including generalized linear models, multiple adaptive regression splines, random forests, and boosted regression trees. We used the mean of the four modeling techniques for ensemble modeling, which has been shown to provide reliable predictions over other methods (Marmion et al. 2009) and may be ideal for pseudo-absence-based models (Grenouillet et al. 2011; Brown and Yoder 2015).

We assessed ensemble model performance using 10-fold cross validation where 20% of observations were held out to test predictive ability. For each validation, we calculated the area under the receiver operating curve as a measure of relative performance (ROC; Hanley and McNeil 1982). Upon assessing model performance, we used all records to generate final distribution models. We used a threshold in predicted suitability that maximized sensitivity plus specificity to create binary suitable climate niche maps. We assessed the relative importance of climate variables using the function provided in the BIOMOD2 package in R. We used eight global climate models (see Climate Data above) to predict climate niches in 2081–2100 under two potential emissions scenarios (SSP2-4.5 and SSP5-8.5).

Spatial Analyses.—We considered areas potentially climatically suitable under future scenarios if raster cells were predicted suitable under at least six global climate models. We assessed niche overlap between current and future conditions using Schoener's D values (D) and corrected modified Hellinger distance (I), which each range 0–1 where 1 = complete niche overlap (Warren et al. 2008). Using R statistical software, we created rasters of suitable climate predictions using the "raster" package (Hijmans and van Etten 2019) and estimated niche overlap with the "dismo" package (Hijmans et al. 2017). We compared niche overlap under current conditions and SSP245 and SSP585 scenarios. To assess potential expansion or contraction of suitable climate conditions, we calculated the geographic area of suitable climate conditions for current and future scenarios using the "area" function in the "raster" package (Hijmans and van Etten 2019). We assessed loss of suitable climate within the current range by calculating the total predicted suitable area under each scenario within the estimated current distribution. Last, we estimated the spatial shift in suitable conditions by first averaging the latitude and longitude of the centroid of all suitable raster cells to generate a weighted centroid for each suitability map. Next, we measured the straight-line distance between the centroids of current and future scenarios to obtain the predicted spatial shift.

Site-level Analysis

Data Collection.—We utilized the 2,351 known Spotted Turtle sites in the eastern United States that were delineated as described in Chapter 2. For each site, we calculated 30-year climate normals (for the years 1970–2000) as well as future projected climate variables for the year 2050 using WorldClim Version 2 raster data (4.5 km^2) (www.worldclim.org; Fick and Hijmans 2017). We utilized the Beijing Climate Center Climate System Model (BCC-CSM1-1) for projections as it has been well supported in having high predictive efficacies by climate scientists (Xiaoge et al. 2019; Chang-Yi et al. 2022) and assessed BCC-CSM1-1 best case (rcp 2.6) and worst case (rcp 8.5) scenarios as representative concentration pathways for greenhouse gas emissions. For normals and the two projected scenarios, we calculated minimum January and maximum July temperature (°C), and average annual precipitation (mm).

Spatial Analysis.—All spatial analysis was performed in ArcGIS. To make annual precipitation datasets for normals and the two future scenarios, monthly precipitation rasters were summed together for their respective group (year/rcp) using the mosaic to new raster tool. Only January minimum and July maximum temperature datasets were used, as temperatures in these months represent the annual minimum and maximum temperatures (NOAA 2020). Feature To Point tool was performed to place a point feature in the center of every Spotted Turtle site. To attribute each Spotted Turtle site with climate data, we used extract multi values to points for the normal data (1970–2000) and the two climate projections (rcp 2.6/rcp 8.5) for each of the three variables: annual precipitation, maximum July temperature and minimum January temperature. Delta values were calculated for each site based on the difference in normals and rcp climatic data and these were averaged across each state.

Results

Distribution Models

The final distribution model was largely driven by the minimum temperature of the coldest month (Figure 10-1).

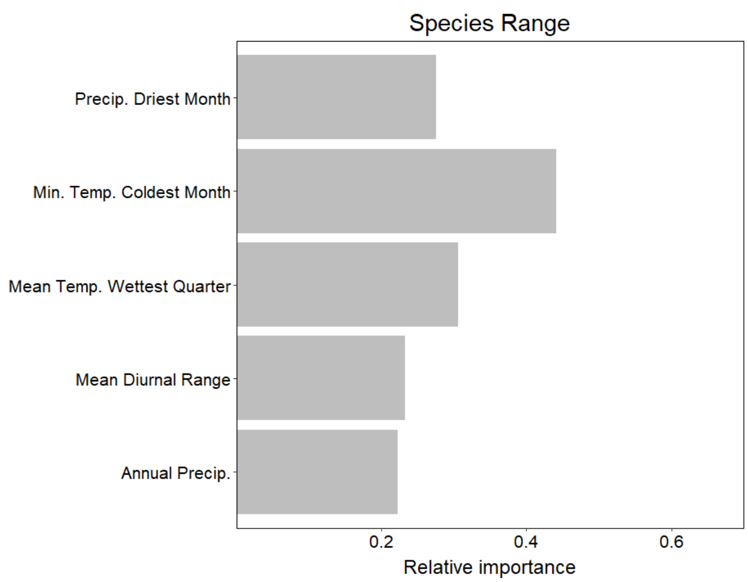
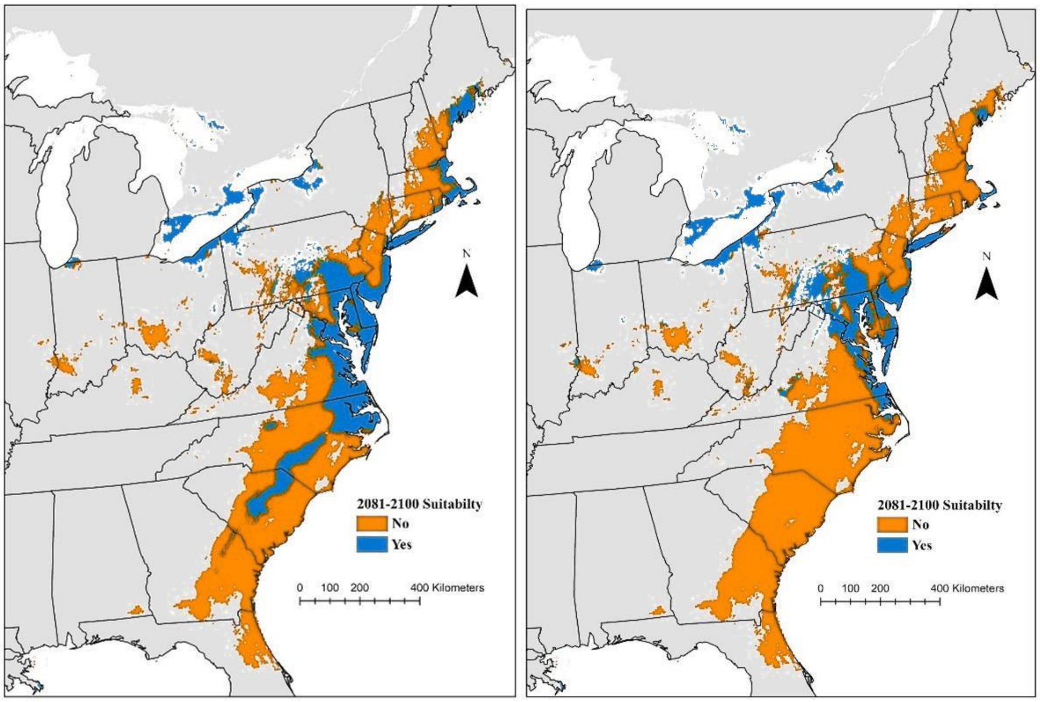


Figure 10-1. Relative importance of bioclimatic variables used in the final model.

Climate forecasts suggest there will be major climatic change within a large majority of the species range within the coastal portion of the range by 2081–2100 under both scenarios (Map 10-1).



Map 10-1. Extent of current distribution predicted to be suitable or not suitable in 2081–2100. Image on the left shows SSP245 predictions and the image on right shows SSP585 predictions. The distribution of suitable future climate primarily shifted northward with the centroid shifting from coastal Virginia, 469 km to northern Pennsylvania under intermediate change (SSP245) and 635 km to western New York under extreme scenarios (SSP585; Table 10-1).

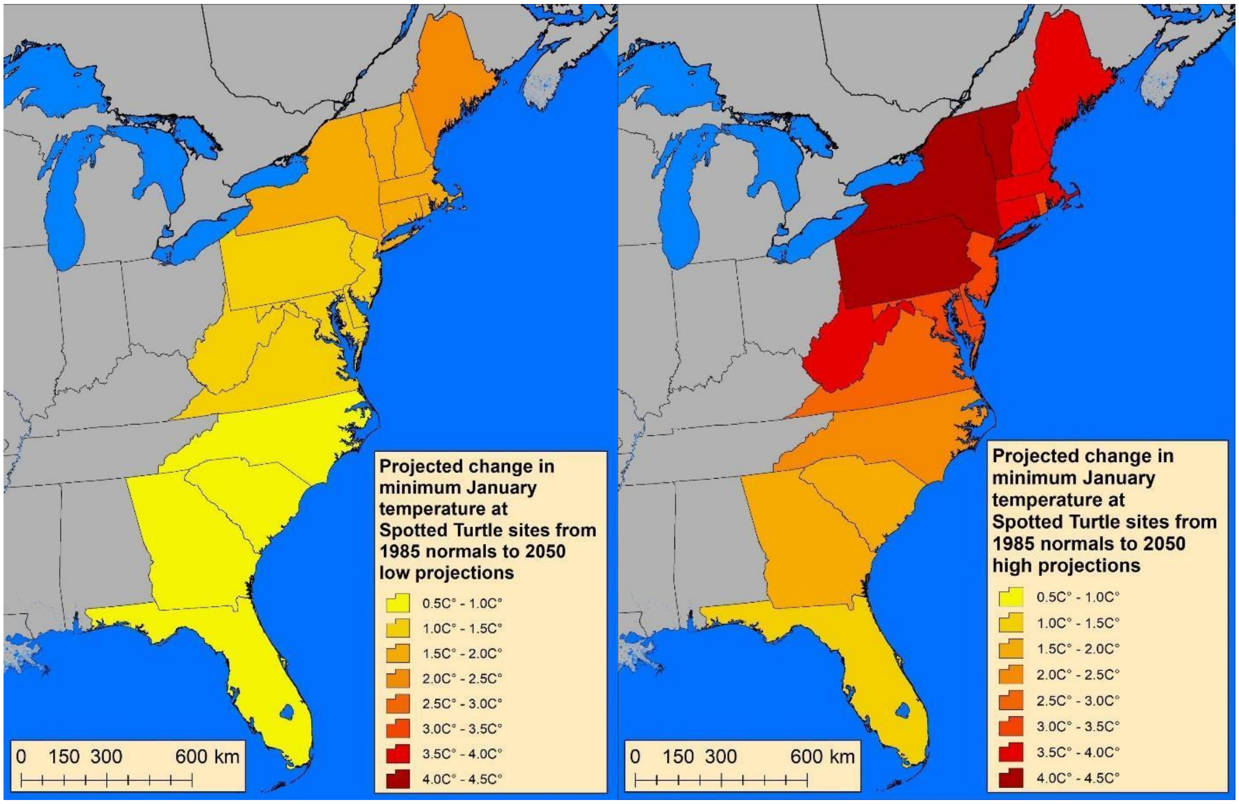
Table 10-1. Spatial shift in distribution centroid under intermediate (SSP245) and extreme (SSP585) emissions scenarios.

Scenario	Distance (km)
Intermediate (SSP245)	468.8
Extreme (SSP585)	634.5

Site-level Analysis

In the following analysis and associated maps and figures, the Beijing Climate Center Climate System Model (BCC-CSM1-1) was the predicting Global Climate Model used showing the lowest 2050 emission scenario rcp 2.6 and highest 2050 emission scenario rcp 8.5. Climate data were retrieved from the Worldclim website www.worldclim.org (Fick and Hijmans 2017).

Under moderate warming scenarios, minimum January temperatures are projected to increase most (2.0–2.5˚C) for Spotted Turtle sites in Maine, while most extreme scenarios project an increase in minimum January temperatures of 4.0–4.5˚C at Spotted Turtle sites in Pennsylvania, New York, and Vermont by the year 2050 (Map 10-2). Figure 10-2 shows variation by sub-region of the eastern United States.



Map 10-2. Average projected change in January minimum temperature for known Spotted Turtle sites in each eastern state from 1970–2000 normals to 2050.

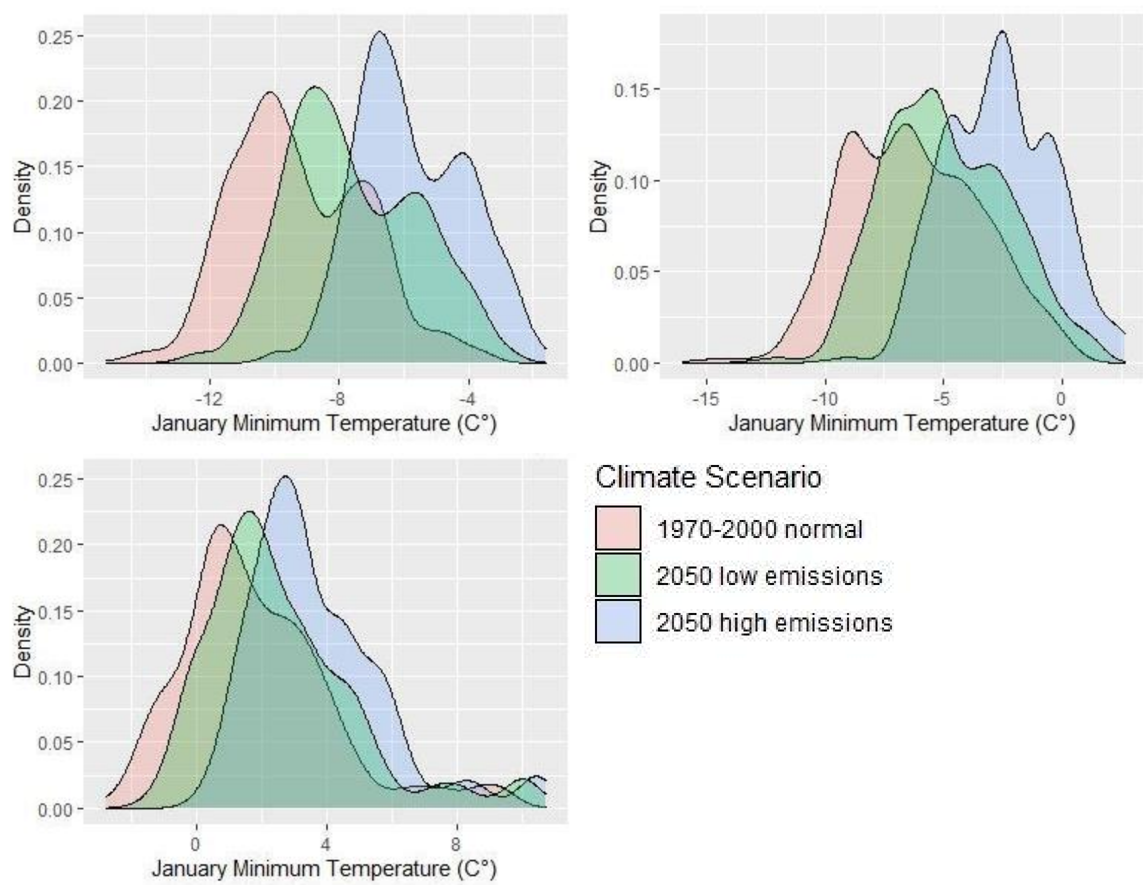
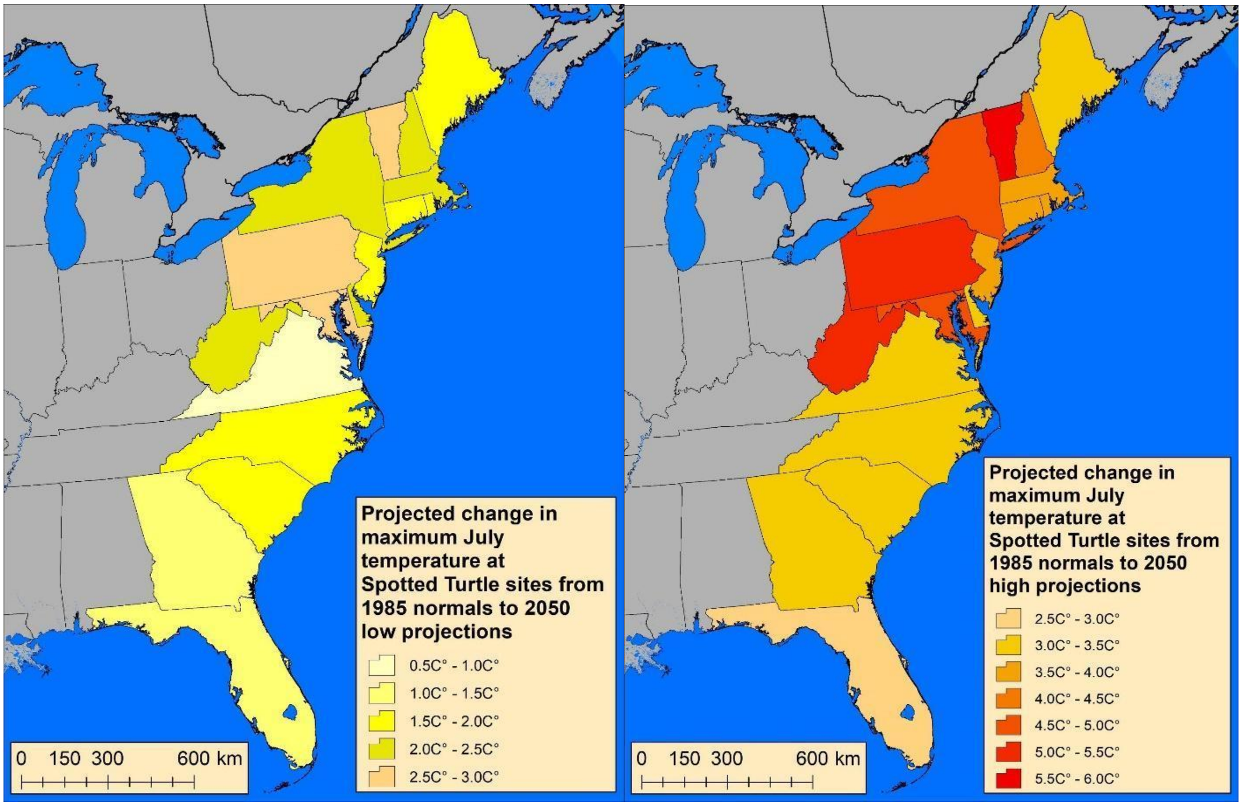


Figure 10-2. Historical normal and projected January minimum temperatures at Spotted Turtle sites in the Northeastern (top left), Mid-Atlantic (top right), and Southeastern (bottom left) regions.

Under moderate warming scenarios, maximum July temperatures are projected to increase from 2.5–3.0˚C for Spotted Turtle sites in Maryland, Pennsylvania, and Vermont. However, extreme scenarios project a 5.5–6.0˚C increase in maximum July temperatures for states in the Mid-Atlantic through the Northeast by 2050 (Map 10-3). Projected increases under the high emissions scenario are outside the current range of variation in each of the three regions (Figures 10-3).



Map 10-3. Average projected change in July maximum temperature for known Spotted Turtle sites in each eastern state from 1970–2000 normals to 2050.

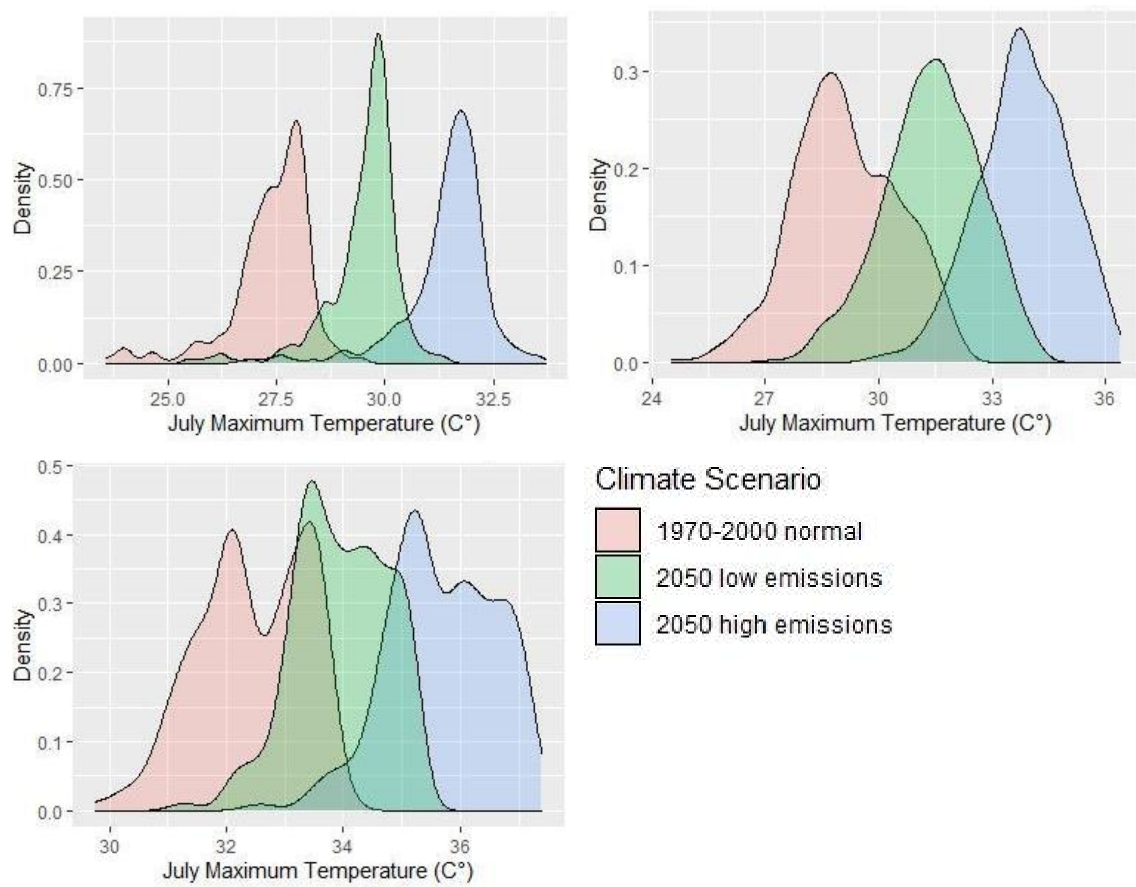
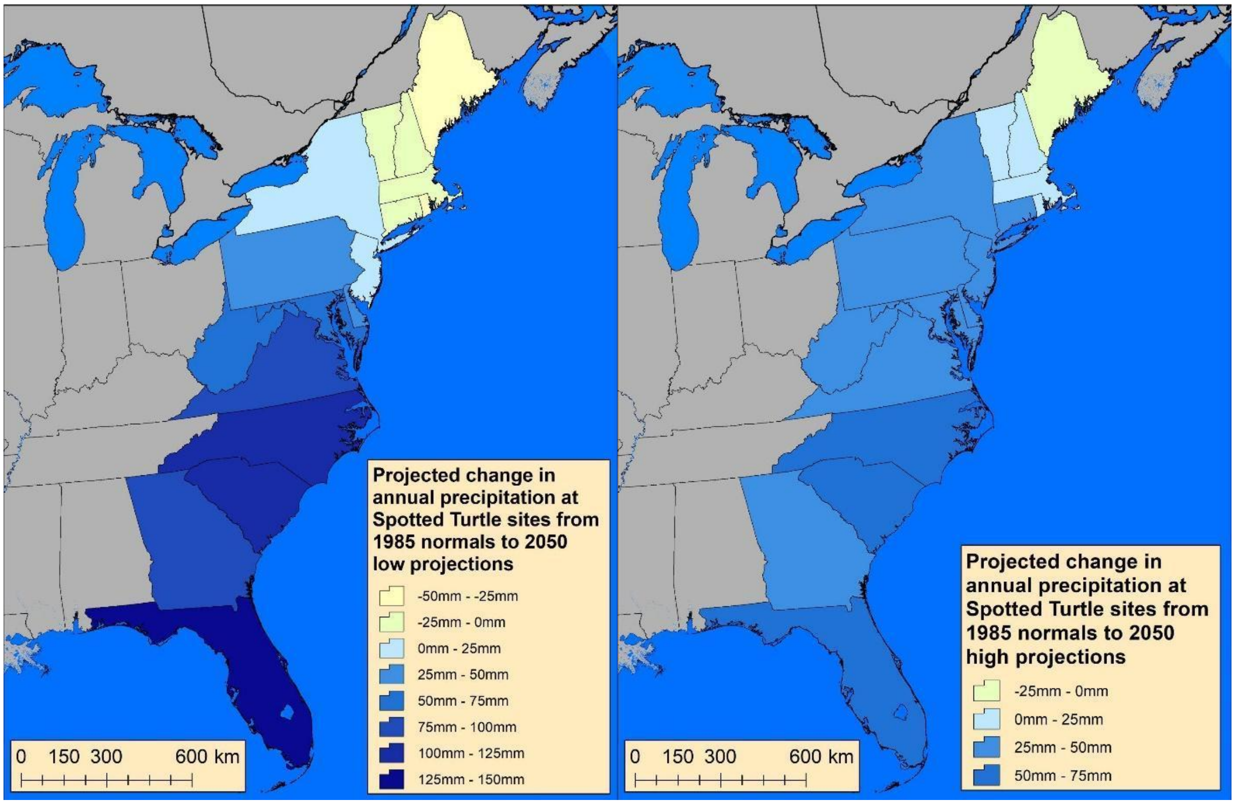


Figure 10-3. Historical normal and projected July maximum temperatures at Spotted Turtle sites in the Northeastern (top left), Mid-Atlantic (top right), and Southeastern (bottom left) regions.

Under low emission scenarios, precipitation is projected to increase an annual average of 15 cm at Spotted Turtle sites in Southern states, while decreasing slightly in Northeastern region (-50–0 mm). The higher emission scenario shows a similar state trend in precipitation at Spotted Turtle sites when compared to the low emission scenario but with less variation (Map 10-4). In the Northeastern region, both the low and high precipitation emission scenarios do not overlap current conditions at Spotted Turtle sites (Map 10-4). Figure 10-4 shows variation by sub-region of the eastern United States.



Map 10-4. Average projected annual precipitation for known Spotted Turtle sites in each eastern state from 1970–2000 normals to 2050.

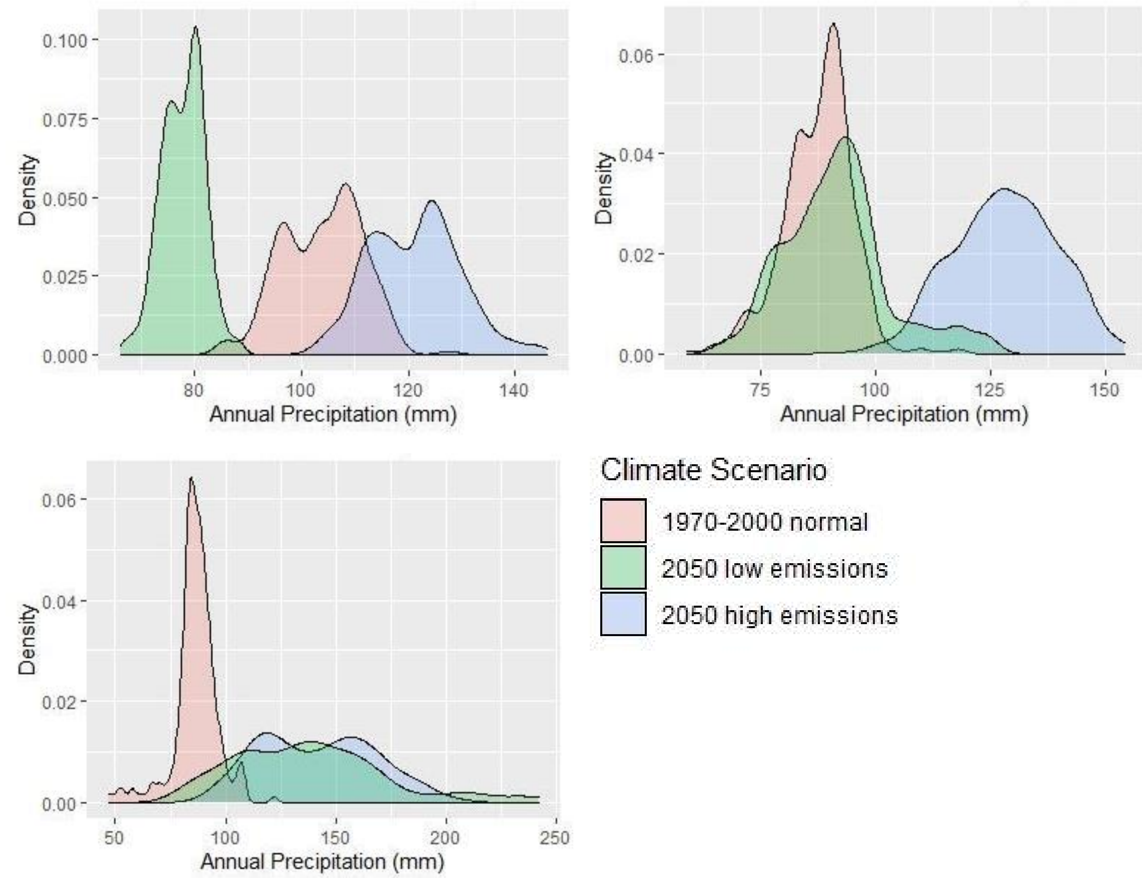


Figure 10-5. Historical normal and projected annual precipitation in Spotted Turtle sites in the Northeastern (top left), Mid-Atlantic (top right), and Southeastern (bottom left) regions.

Discussion

Poikilotherms are highly vulnerable to climate change (Berggren et al. 2009; Sinervo et al. 2010) and turtles—with limited adaptive capacity due to long generation times and limited dispersal ability—are considered particularly susceptible (Gibbons et al. 2000; Barrows 2011; McCoy et al. 2011; Butler 2019). This distribution model assessment suggests climate conditions within most of the current Spotted Turtle range will be dramatically altered by the end of the 21st century unless global emissions are drastically curtailed. However, the ways in which these changes will affect Spotted Turtle populations are unknown and the mechanisms by which populations might change (via changes in mortality or recruitment) have yet to be explored. For instance, we do not know where Spotted Turtles are thermally limited (rather than limited by competitive exclusion or other factors) or understand the ways that an increase in January temperature might affect Spotted Turtle populations on the ground, and whether these areas will actually become unsuitable, only that they will be climatically different than locations where Spotted Turtles occur today. Populations are likely to be affected differently in different parts of the species range, and behavioral adaptations may be available to mitigate those changes to an extent.

Looking at the site-level, relatively rapid temperature increases and shifts in precipitation regimes in the next 30 years could influence individual turtles' behavior and mortality rates, as well as reproductive success, and the viability of Spotted Turtle populations. Poikilotherms rely on relatively stable temperature gradients to necessitate their reproductive cycle and survival (Stevenson 1985; Gilchrist 1995; Lara-Reséndiz et al. 2015). With climate change increasing temperatures, individual Spotted Turtles within northern populations will need to temporally adapt their behavior (overwintering, mating, nesting, aestivation) to match the dynamic and changing temperature regime (Litzgus and Brooks 2000; Haxton and Berrill 2001; Rasmussen and Litzgus 2010*b*; Yagi and Litzgus 2013; Markle et al. 2021). Since Spotted Turtles are a long-lived species and generational adaptation would be slow, this would require individuals to adapt their behavior (Reeves and Litzgus 2008; Buchanan et al. 2019*b*). With moderate temperature projections this could be plausible with northern populations shortening their overwintering period and increasing their active period, similar to present-day southern populations (Haxton and Berrill 2001; Stevenson et al. 2015). However, unpredictable shifts in precipitation combined with warming climate could result in increased mortality from dehydration or overheating (Ward et al. 1976; Yagi and Litzgus 2012).

It appears that Spotted Turtle populations in the Southern extent of their range may already be at their thermal gradient maximum and thus even small temperature increases in these areas could result in elevated mortality rates (Meylan 2006; Stevenson et al. 2015; Chandler et al. 2020). However, it is unknown how individual Spotted Turtles or populations will respond to these changes, and additional information is needed to assess change over time.

Already, there is evidence of morphological and behavioral variation in Spotted Turtles in response to climate. For example, Spotted Turtles appear to display patterns in body size that approximate Bergmann clines, showing a positive relationship between carapace length and latitude (Litzgus et al. 2004; personal communication, Eastern Spotted Turtle Working Group). While the causal factors are unknown, hypotheses suggest that turtles may be larger in colder environment due to the need to produce larger clutches when there is not enough time for multiple clutches in a year (Fecundity Hypothesis; Litzgus et al. 2004), because the physiology of larger bodies allows individuals to sustain larger periods of dormancy (Seasonality/Fasting Hypothesis; Ashton and Feldman 2003), and/or the fact that larger bodies confer greater hypoxia tolerance in cold temperatures (Santilli and Rollison 2018). In addition, Spotted Turtles also display variation in nesting behavior, with individuals often nesting in dry, exposed soils where it is colder, and in wet and/or shaded areas where it is hotter (Lawler et al. 2015; see Chapter 11 for additional analysis on this topic). Both patterns suggest that local adaptation is occurring and there may be some possibility for morphological and behavioral plasticity to offset climate effects.

Turtles have endured substantial changes in climate over evolutionary timescales, but never at a rate similar to contemporary climate change (Poloczanska et al. 2009). Provided that conditions do not exceed critical thermal maxima for survival (Hutchison et al. 1966; Stralberg et al. 2018), the extreme longevity (Gibbons 1989) exhibited by turtles will likely allow individuals to exist for decades outside of their adapted climate envelope (Spinks et al. 2003). Thus, the effect of climate change on turtles will prove challenging to observe even well after suitable conditions have left populations behind, severely complicating the already considerable challenge of mitigating the effects of climate change on this taxon. The results of these analyses suggest widespread climatic change of habitat and highlight the importance of considering climate change — in addition to the myriad other factors affecting this species — in future research and as conservation efforts progress.

Chapter 11. How Climate Change and Anthropogenic Land Use Relate to Spotted Turtle Demographic Parameters

H. Patrick Roberts

Introduction

Climate change and land-use change were identified as major threats to Spotted Turtle populations by experts (Appendix 1-A) and are leading drivers of biodiversity decline, affecting demographic parameters that are important for population persistence (Selwood et al. 2015). Species displaying temperature-dependent sex determination (TSD; Bull et al. 1982) are considered particularly vulnerable to climate and land-use change because variation or directional change in temperatures experienced by developing embryos may skew sex ratios, potentially triggering population decline or extirpation (Janzen 1994*a*; Schwanz et al. 2010). In some species, land-use may also induce differential mortality among sexes (Steen and Gibbs 2004), which has the potential to compound — or conceal — the effects of climate change and land use on embryo development (Reid and Peery 2014). However, the effects of land-use on sex-specific mortality may not be straightforward, with factors such as habitat configuration, which can determine movement patterns among sexes, potentially modulating this relationship. Disentangling the factors influencing population demographics represents an important research priority that will facilitate more effective conservation strategies as global change progresses (Janzen 1994*a*; Reid and Peery 2014). The aim of this study was to examine the combined relationship between climate change and land use and sex ratios of Spotted Turtles throughout its geographic range. We predicted that population sex ratios would be female-biased in areas that had experienced the most warming compared to mean historic temperature because warmer temperatures produce females (Figure 11-1a; i.e., Type Ia TSD; Ewert et al. 2004). Additionally, in areas with high levels of land cover that may increase mortality, we predicted that populations associated with aggregated wetlands would be male-biased due to increased vulnerability of females while nest-searching, but unbiased in wetlands that were more dispersed due to similar rates of mortality between sexes resulting from non-nesting inter-wetland movements (Figure 11-2).

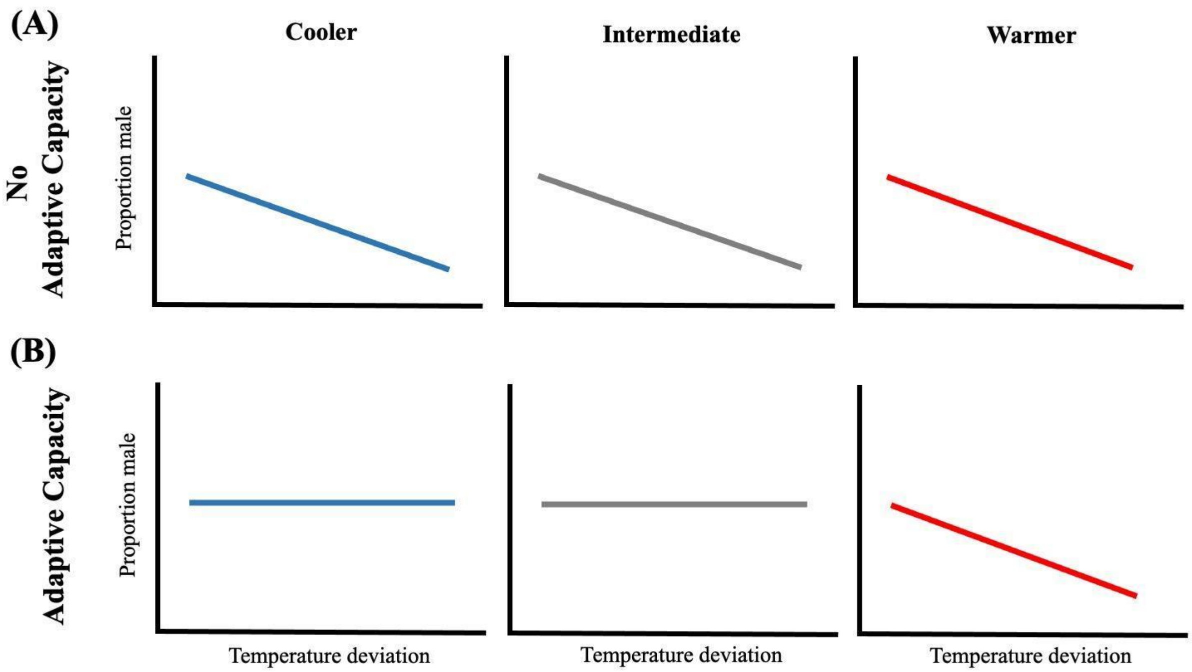


Figure 11-1. Diagram depicting our expectations regarding how climate change might influence population sex ratio of the Spotted Turtle (*Clemmys guttata*). We predicted similar relationships between sex ratio and climate change regardless of historical climate (A). Alternatively, under an adaptive capacity scenario, we expected no relationship between sex ratio and climate change except in the warmest portions of the range where populations cannot counter climate change through plasticity in nesting behavior because suitable nesting locations are rare or do not exist (B)

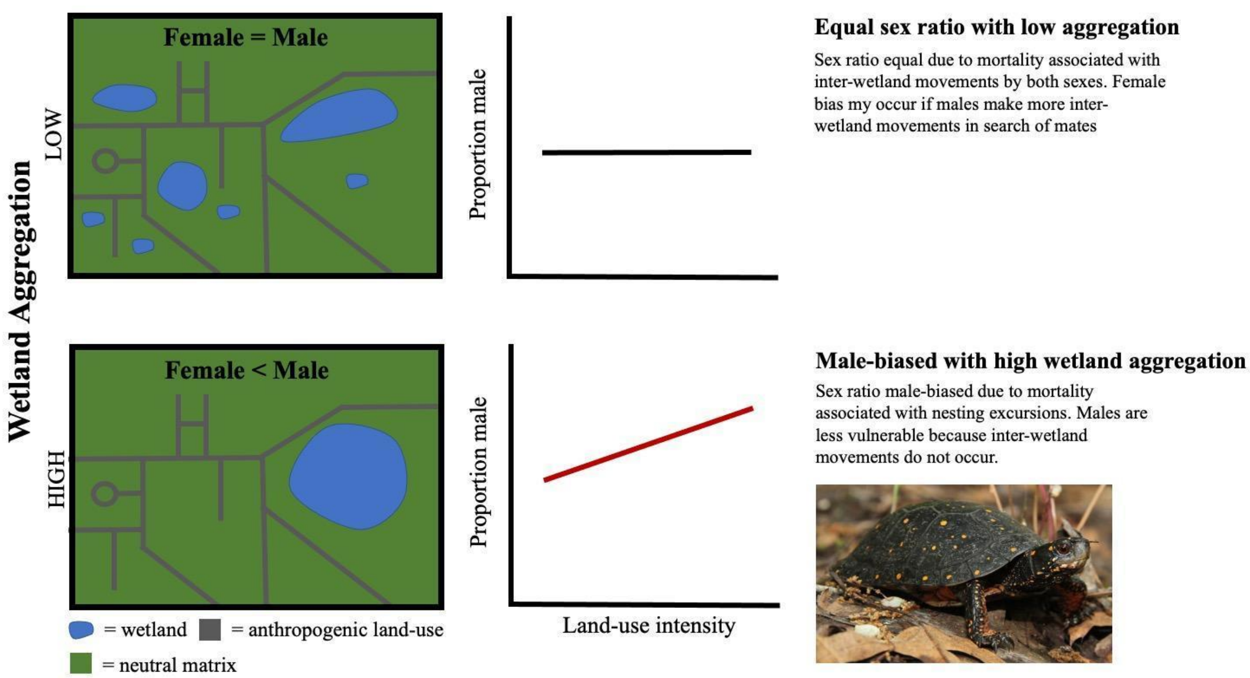


Figure 11-2. Diagram depicting our predictions regarding how landscape structure and land use might influence population sex ratio of the Spotted Turtle (*Clemmys guttata*). Photo credit: Michael T. Jones.

Methods

Population Sampling

Over 100 state, federal, academic, and nonprofit partners sampled Spotted Turtles from Maine to Florida using a standardized sampling protocol (see Part III of this document for details). While in the field, we determined the sex of adult turtles based upon the presence (male) or absence (female) of a plastron concavity and the coloration of the chin and throat (tan in males, orange in females; Ernst and Lovich 2009).

Environmental Covariates

Climate.—We used 4-km resolution PRISM Climate data (PRISM Climate Group) to estimate measures of mean annual deviation from "historical normal" for temperature (daily mean and maximum temperature) and precipitation (daily mean precipitation) in the months of June and July. We chose June and July because nests incubate during these months across the range, and previous research has linked hatchling sex ratio to mean July temperature (Janzen 1994*a;* Schwanz et al. 2010). We defined "historical normal" as the 30-year mean centered around 1959 (1944–1973), and estimated deviation from normal by first (1) calculating the difference from normal for each trapping location in each year from 1960–2009, then (2) calculating the mean deviation from normal across all years and traps for each sub-plot. We chose this 50-year temporal window from 1960–2009 because it represents the period within which most turtles included in this study likely hatched. We extracted climate values for each trap location using the raster package (Hijmans and van Etten 2019) in R statistical software version 4.0.2 (R Core Team 2021).

Land Cover and Landscape Structure.—We calculated land cover variables at multiple spatial scales. "Local" scales consisted of circular buffers ranging from 30–300 m at 30-m increments and were intended to encompass the typical home range of most individual Spotted Turtles. "Landscape" scales, which consisted of circular buffers of 480-, 960-, 1,920-, 3,840-, and 7,680-m radii, were intended to reflect the broader landscape beyond a typical Spotted Turtle home range while encompassing values of extreme long-distance movements (e.g., Milam and Melvin 2001), the scale of predatory threats (e.g., movements by raccoons [Prange et al. 2004]), and broader landscape-level processes such as disturbance regimes, ecosystem function, and/or dispersal (Roberts et al. 2021).

We derived land cover variables from the 2016 National Land Cover Database (NLCD), Urban Imperviousness, and Tree Canopy raster data layers developed by the Multi-Resolution Land Characteristics Consortium (Coulston et al. 2016; Yang et al. 2018; Jin et al. 2019). Land cover variables included road density, percent canopy cover, percent imperviousness, proportion hay/pasture fields, and proportion cultivated crops. We chose these variables because we expected they could cause direct adult mortality (Roberts et al. 2021) and/or influence incubation temperatures (Ewert et al. 2005; Freedberg et al. 2011), both of which could affect population sex ratios. We excluded commercial cranberry bogs from the cultivated crops variable because this represents an uncommon crop type throughout the range and, unlike other cultivated crops, may provide suitable habitat for Spotted Turtles. Developed land included all NLCD cover types classified as "developed." We calculated each variable at each spatial scale (buffer) for all 30-m raster cells within the study area using the Focal Statistics tool in ArcGIS (Environmental Systems Research Institute, Inc., Redlands, CA). We estimated percent canopy cover and percent imperviousness by calculating the mean of all cells within each buffer. We estimated the remaining variables by taking the proportion of cells within each buffer. We extracted covariate values for each scale for each trap location using the raster package (Hijmans and van Etten 2019) in R. We calculated the mean across all five traps within each sub-plot.

We calculated the degree of wetland aggregation using the Aggregation Index (AI) metric in FRAGSTATS software version 4.2 (McGarigal et al. 2012). This metric characterizes the relative aggregation of a given cover type and is defined as the number of alike raster cell adjacencies divided by the total possible cell adjacencies. We measured AI from the centroid of sub-plot trap locations and only used wetlands that were classified as emergent, shrubland, and forested in the National Wetland Inventory database (NWI). These represent the primary wetland types that Spotted Turtles occupy throughout their range (Ernst and Lovich 2009). We converted NWI wetland shapefiles to a 30-m raster using ArcGIS. Because our goal was to characterize large-scale patterns, we only estimated this class for larger spatial scales ≥ 300 m. In some contexts, AI can be correlated with the amount of habitat on the landscape (Neel et al. 2004); therefore, we checked Pearson correlations for each scale, which ranged from 0.43 at 300 m to 0.7 at 7,680 m.

Statistical Analyses

We related sex ratio (the proportion of individual male turtles) at sub-plots to environmental covariates using generalized linear mixed models using the "glmmTMB" package in R (Brooks et al. 2017). Because sub-plots were inherently spatially clustered, and a small number of sites (groups of four sub-plots) were placed near each other, we included "macrosite," which we defined as all sub-plots separated by ≤two km, as a random effect to account for a lack of independence among sub-plots in close proximity. We chose the two-km separation distance to define macrosites because, upon visual inspection of sub-plot locations, this distance reflected the obvious spatial clustering pattern (i.e., to include more sub-plots within clusters would have required a much larger separation distance). We removed one sub-plot from analyses because wetlands were not mapped at this location in the NWI dataset. We used a binomial error distribution with proportion of individuals that were male as the response variable. Following Steen and Gibbs (2004), we only modeled sex ratios for sub-plots that captured ≥10 unique adult turtles.

We used a multi-stage process (Appendix 11-A) to conduct model selection, employing Akaike's Information Criterion corrected for small sample size (AICc; Burnham and Anderson 2002) to compare the performance of models. We selected climate variables for consideration in final model selection by comparing the performance of models with each climate differential variable alone, as well as including an interaction with the historical normal temperature. We considered these interactions because we suspected that the relationship between male proportion and mean deviation from normal might vary depending upon typical local temperature (Figure 11-1b). For example, individuals in areas that are historically warmer (e.g., southeastern U.S.) might already nest in the coolest locations (e.g., forest or near water), and therefore not have cooler nesting locations available to maintain an ideal sex ratio. We selected climate variables for consideration in final model selection if they appeared in models with ΔAICc < 2 and had 95% CI that did not overlap zero.

Last, we conducted final model selection by comparing all variable subsets using the "MuMIN" package (Barton 2016) in R. We examined variance inflation factor scores of top models to ensure excessive multicollinearity was not present. We only considered models with six or fewer fixed effect covariates to limit the potential of over-fitting models. We considered variables to be supported if they appeared in models with ΔAICc < 2, and strongly supported if the 95% CI excluded zero (Chandler et al. 2009).

Results

We captured ≥10 individual adult turtles at 58 sub-plots surveyed between 2017 and 2020. These sub-plots were distributed across 12 states, including Florida (1), Georgia (3), Virginia (8), West Virginia (6), Maryland (7), Delaware (8), New York (3), Rhode Island (1), Massachusetts (11), Vermont (1), New Hampshire (3), and Maine (6). The proportion of individuals that were males captured at these sub-plots ranged from 0.15–0.90 (μ = 0.57) across the study area.

An interaction between mean maximum temperature differential and historical normal maximum July temperature was strongly supported and appeared in the second-best performing model (Table 11-1). Where maximum temperatures in July were historically higher, the proportion of male individuals displayed a negative relationship with increasing temperatures, but in historically cooler areas this relationship reversed (Figure 11-3). An interaction between cultivated crops and wetland aggregation within 300 m was strongly supported and appeared in all top models (Table 11-1). The proportion of male individuals captured was negatively related to cultivated crops at low levels of wetland aggregation but showed only a slight positive relationship with cultivated crops at high aggregation (Figure 11-4). Proportion of cultivated crops within 7,680 m showed a strong positive relationship with male proportion for the best performing model (Table 11-1; Figure 11-5).

Table 11-1. Coefficients (standard error) of best performing models relating the proportion of male turtles captured to environmental land cover and climate covariates. Asterisks indicate coefficients with 95% confidence intervals that do not overlap zero.

Wetland Aggregation[a] (300 m)	Crops[b] (300 m)	Crops-Aggregation Interaction[c]	Crops[b] (7680 m)	July Max. Temp. Deviation[d]	July Max. Temp. Normal[e]	July Max. Temp. Interaction[f]	AICc[g]	ΔAICc	w[h]
–0.2 (0.09)*	–0.06 (0.05)	0.14 (0.04)*	0.16 (0.05)*				247.1	0	0.58
–0.12 (0.09)	–0.06 (0.05)	0.12 (0.04)*		0.07 (0.1)	0.1 (0.08)	–0.17 (0.07)*	247.7	0.7	0.42

[a]Index characterizing the degree of wetland aggregation within 300 m
[b]Proportion cultivated crop cover within 300 m and 7,680 m
[c]Interaction between proportion crop cover and wetland aggregation within 300 m
[d]Mean annual deviation of maximum July temperature from 1959 30-year normal for 1960–2009
[e]1959 30-year normal; mean maximum temperature from 1944–1973
[f]Interaction between mean July max. temp. deviation from normal and the 1959 30-year normal
[g]Akaike's Information Criterion corrected for small sample size
[h]AICc model weights

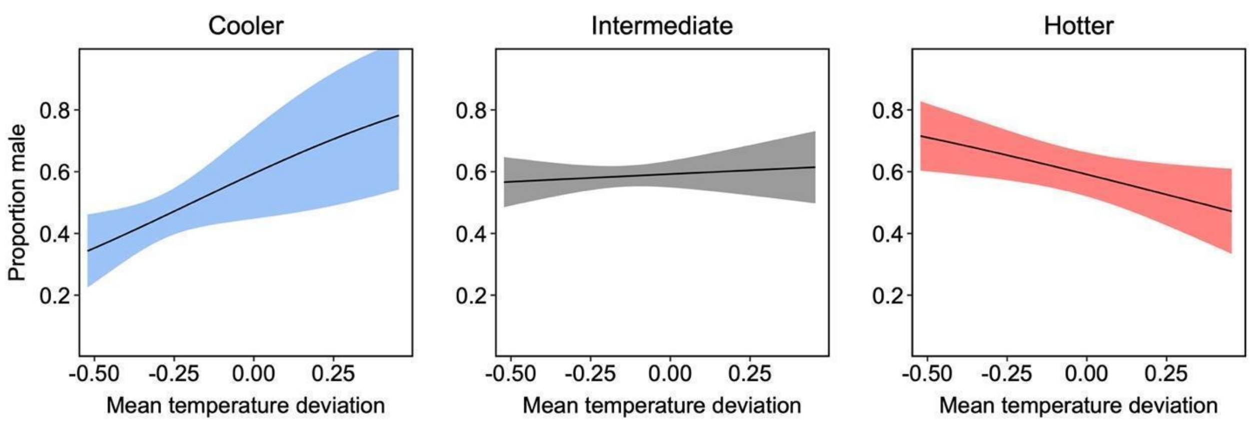


Figure 11-3. Observed relationship between male Spotted Turtle (*Clemmys guttata*) proportion of captures and the mean annual deviation of maximum July temperature (1960–2009) from the historical normal at low (10th percentile), intermediate (mean), and high (90th percentile) historical normal temperatures.

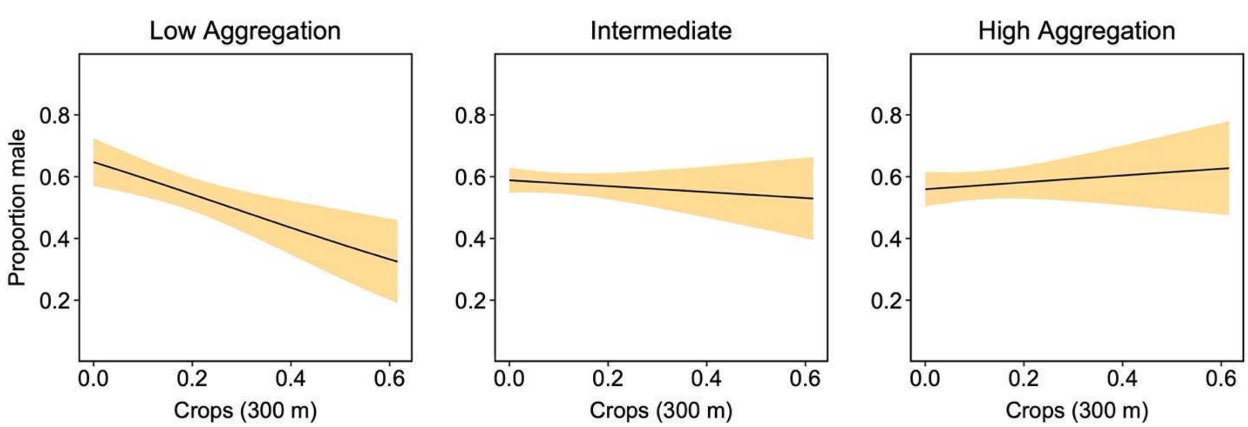


Figure 11-4. Observed relationship between male proportion of captures and the proportion of cultivated crop cover within 300 m at low, intermediate, and high aggregation wetland suitable for Spotted Turtles (*Clemmys guttata*; defined at emergent, shrub, and forested wetlands combined).

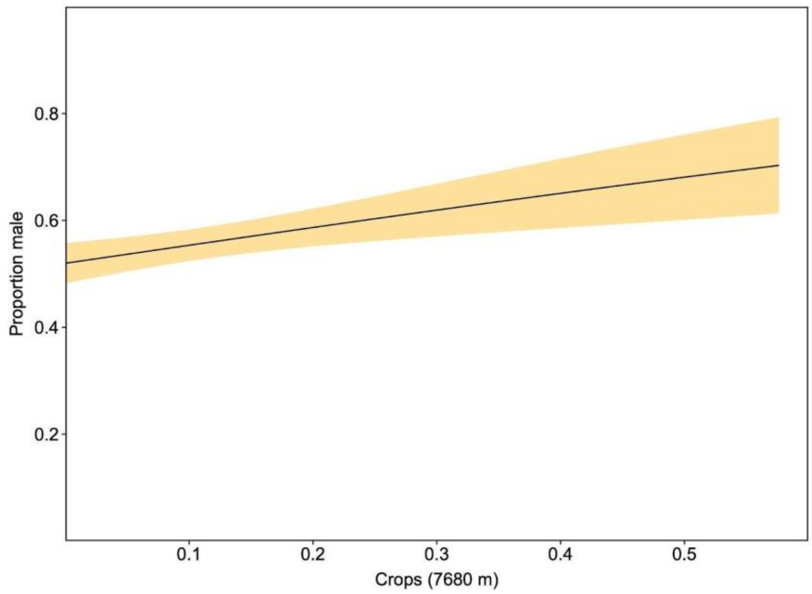


Figure 11-5. Observed relationship between male Spotted Turtle (*Clemmys guttata*) proportion of captures and proportion cultivated crop cover (7,680 m) in best performing model. To generate this prediction, all other explanatory variables were held at their mean.

Conclusions

Our study suggests that climate change may be driving sex ratio imbalances of Spotted Turtles in a manner that varies profoundly depending upon local climate. While warming trends appear to be driving both female- and male-biased ratios at warmer and cooler portions of the range respectively, our results suggest that at intermediate temperatures, Spotted Turtles may be able to buffer the effects of a changing climate. However, the rate of climate change will likely overcome the ability to compensate — as appears to be the case in the warmest portions of the range — and an increasing number of populations may trend toward female bias. While female-bias may initially benefit populations through increased growth rates (Tomillo et al. 2015), if ratios become severely skewed it will eventually negatively affect viability (Hays et al. 2017), although it is unclear at what point this will occur.

While climate change represents a major long-term threat to population persistence on multiple fronts (Ihlow et al. 2012), our results, which include land cover in all top models, support the notion that anthropogenic land use, not climate, is the predominant factor influencing adult sex ratio of Spotted Turtles and other freshwater turtles (Reid and Peery 2014). While the effect of climate change on sex ratio may present a future threat to freshwater turtle demographics, the influence of anthropogenic land use represents a more immediate and influential driver of sex ratio imbalances, likely through its effect on sex-specific mortality rates and microclimate.

Chapter 12. Influence of Sea Level Rise on Spotted Turtle Populations

Molly K. Parren, Cullen Mackenzie, Nadya Bennet, and Savannah Kerns

Introduction

In 2019, the United Nations' Intergovernmental Panel on Climate Change (IPCC) released a special report on the impacts of climate change on the ocean and cryosphere (IPCC 2019). This report estimates that human activities have caused approximately 1˚C in global warming above pre-industrial levels and, as a result, the global mean sea level (GMSL) is rising, and the rate of that rise is accelerating (IPCC 2019). GMSL increased at a rate of 0.4 mm yr from 1901 to 1990, 2.1 mm yr from 1970 to 2015, 3.2 mm yr from 1993 to 2015, and 3.6 mm yr from 2006 to 2015 (IPCC 2019). Current sea level rise (SLR) is primarily driven by the melting of glaciers and ice sheets but is also caused by thermal expansion as the ocean absorbs excess heat and land water storage changes (e.g., groundwater pumping and subsidence; IPCC 2019). Projected SLR is largely dependent on future emissions and will likely be between 0.43 and 0.84 m by 2100 but could reach 1.10 m (IPCC 2019). Expected impacts of SLR on coastal ecosystems include habitat contraction, loss of functionality and biodiversity, and lateral and inland migration (IPCC 2019). Inundation, coastal erosion, and salinization are already causing inland shifts in plant species distributions (IPCC 2019). However, human development blocks migration, increasing coastal ecosystems' vulnerability to SLR (IPCC 2019). Global coastal wetland area has already declined by nearly 50% relative to pre-industrial levels and will lose an additional 20−90% of its remaining area depending on the future emissions scenario (IPCC 2019).

Storm Surge and Overwash

SLR amplifies the impacts of storm surge, high tides, coastal erosion, and wetland loss (Sweet et al. 2022). At higher relative sea levels, coastal flooding can be caused by common wind events and seasonal high tides, rather than powerful storms (Sweet et al. 2022). Additionally, over the past few decades, both the intensity of hurricanes (Bhatia et al. 2019) and the height of extreme waves in the North Atlantic have increased, contributing to extreme sea level events, coastal erosion, and flooding (IPCC 2019).

During intense weather events, storm surge and waves wash over beaches and dunes, depositing sand and other forms of sediment into the "backbarrier" environment (Donnelly et al. 2009; Walters and Kirwan 2016). This process is referred to as "overwash" and can have both positive and negative impacts on coastal habitats. The deposition of sediment as a result of overwash can benefit coastal habitats by linking barrier islands and coastal marshlands, adding valuable nutrients which enhance plant productivity and the formation of new roots and shoots, and elevating marshland soils which enable vegetation accretion, resiliency, and aeration (Mendelssohn and Kuhn 2003; Baustian and Mendelssohn 2015; Walters and Kirwan 2016). Alternatively, the transport of sand can cause substantial erosion and reduced growth or death of vegetation due to deep sediment burial (Wang and Horwitz 2007; Nikitina et al. 2014; Walters and Kirwan 2016).

By 2050, tide and surge heights will increase due to SLR, leading to a shift in flood regimes along the United States coasts (Sweet et al. 2022). Major and moderate high tide flood events will occur at the frequency that moderate and minor high tide flood events currently occur (Sweet et al. 2022). Increased frequency and severity of coastal flooding will likely result in higher rates of overwash and overwash thickness, which could lead to reduced marsh resiliency (Walters and Kirwan 2016).

Coastal Ecosystems

SLR has been occurring along United States coastlines for centuries, but at a much slower rate than is currently being observed (Church and White 2011). Coastal marshland habitats have, for the most part, successfully survived slower SLR rates through both vertical accretion and lateral inland migration (Holmquist et al. 2021). Vertical accretion refers to the build-up of ground elevation through the deposition of soils which must outpace the rate of SLR in order to sustain marshland vegetation (Kirwan and Megonigal 2013). Alternatively, marshlands can migrate laterally (or inland) to adjacent, un-inundated wetlands (Holmquist et al. 2021). However, in order for marshlands to successfully migrate inland, there has to be space available. With human development increasing along the coastal plains globally, there is often no suitable upland to migrate to. This is sometimes referred to as the ecological "coastal squeeze", where marshlands are trapped between rising sea levels and a human development land barrier termed a "fixed upslope" (Smart et al. 2021). Overtime, increasing rates of SLR-driven saltwater intrusion and human development may outpace coastal marshland habitats' ability to adapt (Ury et al. 2021).

Coastal Spotted Turtles.—Spotted Turtles move between a variety of habitats in order to meet their ecological and biological needs such as mating and nesting, overwintering, and foraging (Beaudry et al. 2009). Coastal marshlands and neighboring wetlands are preferred habitat areas for coastal populations of Spotted Turtles during multiple life-history stages (Agha et al. 2018). When these coastal habitats experience SLR-driven saltwater intrusion and inundation, Spotted Turtles will move to a more suitable habitat patch, if available (O'Dell 2021). However, due to increased human development, often there is no suitable, neighboring habitat available. As a result, Spotted Turtles may be forced to either make longer upland movements, where they will likely encounter other threats like roads, or try to adapt to rising levels of saltwater intrusion.

At the projected unmitigated scenario of one-meter SLR by 2100, 90% of coastal freshwater turtle species could be affected (Agha et al. 2018). The turtle family Emydidae, which includes Spotted Turtles, is projected to be one of the most affected by SLR with a mean percent overlap between projected GMSL and species' ranges of 3.1% (Agha et al. 2018). While Spotted Turtles are classified as "common" in brackish water environments, there has been no evidence of long-term salinity tolerance (Agha et al. 2018). In fact, Spotted Turtles can lose 2.2% of their body mass everyday they are immersed in sea water (Dunson 1986). Therefore, it is unlikely that Spotted Turtles would be able to adapt to high levels of saltwater intrusion.

SLR within Spotted Turtle sites

Background

Relative sea level along the contiguous United States coastline has risen, on average, about 0.3 m in the past 100 years (1920–2020) and is expected to rise another 0.3 m by 2050 (Sweet et al. 2022). The amount of SLR beyond 2050 will be affected by future greenhouse gas emissions, global warming, and ice-sheet dynamics (Sweet et al. 2022). Given the uncertainty in future greenhouse gas emissions (Emissions Uncertainty) and associated ice-mass loss, ocean thermal expansion, and local ocean dynamics (Process Uncertainty; Sweet et al. 2022), there are several possible future SLR scenarios.

The following analysis is based on four of five SLR scenarios which use target GMSL values for the year 2100: Intermediate-Low (0.5 m), Intermediate (1 m), Intermediate-High (1.5 m), and High (2 m; Sweet et al. 2022). While a Low (0.3 m) scenario exists, it has been determined to have a low probability of occurring by 2100 (NOAA Office for Coastal Management 2022*a*) and was excluded from the analysis. Currently, SLR in most United States regions is tracking between Intermediate-Low and Intermediate-High scenarios (Table 12-1), with higher SLR along the East and Gulf Coasts of the United States (Table 12-2; Sweet et al. 2022).

Table 12-1. Observation-based extrapolations and five SLR scenarios, in meters, for relative sea level for the contiguous United States from 2020 to 2150 (relative to a baseline of 2000). Table adapted from Sweet et al. 2022.

Scenario	Short term			Short/Long term	Long term	
	2020	2030	2040	2050	2100	2150
Obs. Extrapolation	0.11	0.19	0.28	0.38		
Low	0.20	0.18	0.25	0.31	0.60	0.80
Intermediate-Low	0.13	0.20	0.28	0.36	0.70	1.20
Intermediate	0.13	0.21	0.30	0.40	1.20	2.20
Intermediate-High	0.13	0.22	0.33	0.46	1.70	2.80
High	0.13	0.22	0.35	0.52	2.20	3.90

Table 12-2. Observation-based extrapolations and regionalized global mean sea level scenario-based estimates, in meters, of relative sea level in 2050 (relative to a baseline of 2000). Table adapted from Sweet et al. 2022.

Scenario (2050)	Contiguous U.S.	Northeast	Southeast	Eastern Gulf
Obs. Extrapolation	0.38	0.40	0.41	0.48
Low	0.31	0.36	0.28	0.30
Intermediate-Low	0.36	0.40	0.32	0.34
Intermediate	0.40	0.43	0.36	0.38
Intermediate-High	0.46	0.49	0.43	0.45
High	0.52	0.54	0.49	0.51

To examine the impacts of different SLR scenarios on coastal Spotted Turtle sites, we used the National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management's Sea Level Rise Wetland Impacts and Migration raster data (NOAA Office for Coastal Management 2022*b*), hereafter "Marsh Migration". This data uses landcover classifications from NOAA's Coastal Change Analysis Program (C-CAP; NOAA Office for Coastal Management 2022*c*) to depict potential impacts on wetland environments at varying levels of SLR. Marsh Migration identifies 13 landcover types broadly grouped as background, development, uplands, freshwater wetlands, salt marsh, unconsolidated shore, and open water.

Marsh Migration assumes that each wetland category has an established tidal elevation range based on its associated vegetation types and their relative tolerance of inundation and salinity (NOAA Office for Coastal Management 2017). The possible distribution of wetland types is determined using a freshwater-upland boundary (elevation is composed of 66% wetlands) and four tidal surfaces: Mean Lower Low Water (MLLW), Mean Tide Level (MTL), Mean Higher High Water (MHHW), and Mean High Water Spring (MHWS; NOAA Office for Coastal Management 2017). Wetland categories are assumed to exist between these thresholds as shown in Figure 12-1 (NOAA Office for Coastal Management 2017).

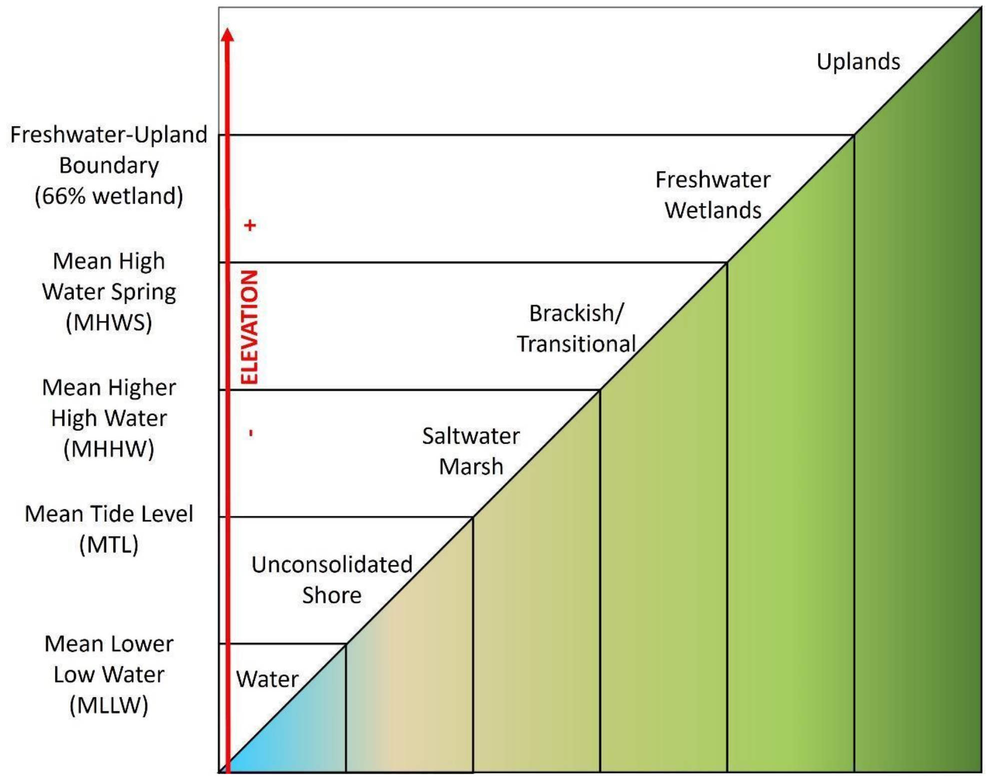


Figure 12-1. The four tide surfaces and freshwater-upland boundary used by Marsh Migration to determine the possible distribution of wetland types: open water, unconsolidated shore, saltwater marsh, brackish/transitional marsh, freshwater wetlands, and uplands. Figure adapted from NOAA Office for Coastal Management 2017.

Tidal thresholds will move up in elevation relative to the land as higher elevations are more frequently inundated due to SLR (NOAA Office for Coastal Management 2017). As a result, marshes will migrate landward as uplands transition to freshwater wetlands, freshwater wetlands transition to brackish/transitional marshes, salt marshes, or unconsolidated beach, and low-lying areas are converted to open water. However, high and medium development classes are classified as barriers to marsh migration, and limit potential landward movement (NOAA Office for Coastal Management 2022*a*).

Methods

To assess the potential effects of sea level rise on Spotted Turtle sites, we used a marsh migration dataset from the NOAA Office for Coastal Management for all sites from Maine to Florida. Marsh migration data come in 10 m resolution raster tiles and are available in 0.5 m increments of SLR from 0–10 ft, for each state. We used the Sea Level Rise Viewer web mapping tool (NOAA Office for Coastal Management 2022*d*) to identify approximate 2020–2100 SLR projections for Intermediate-Low, Intermediate, Intermediate-High, and High scenarios, assuming no accretion, at a single marsh location within each East Coast state (Table 12-3).

Table 12-3. Possible sea level rise, in feet, under different sea level rise scenarios. State measurements are based on single representative measurements (rounded) from each state, assuming there is no accretion.

State	High				Intermediate high				Intermediate				Intermediate low			
Sub-region	**2040**	**2060**	**2080**	**2100**	**2040**	**2060**	**2080**	**2100**	**2040**	**2060**	**2080**	**2100**	**2040**	**2060**	**2080**	**2100**
Maine	1	2	4	6	1	2	3	4.5	1	1.5	2.5	3.5	1	1	1.5	2
New Hampshire	1	2	4	6	1	2	3	4.5	1	1.5	2	3.5	1	1	1.5	2
Massachusetts	1	2	4	6.5	1	2	3.5	5	1	1.5	2.5	4	1	1.5	2	2.5
Rhode Island	1	2	4	6.5	1	2	3.5	5	1	1.5	2.5	4	1	1.5	2	2.5
Connecticut	1	2	4	6.5	1	2	3	5	1	1.5	2.5	4	1	1.5	2	2.5
New England	**1.0**	**2.0**	**4.0**	**6.3**	**1.0**	**2.0**	**3.2**	**4.8**	**1.0**	**1.5**	**2.4**	**3.8**	**1.0**	**1.3**	**1.8**	**2.3**
New York	1	2.5	4.5	6.5	1	2	3.5	5	1	1.5	2.5	4	1	1.5	2	2.5
New Jersey	1	2.5	4.5	7	1	2	3.5	5.5	1	2	3	4	1	1.5	2	2.5
Pennsylvania	1	2.5	4.5	6.5	1	2	3.5	5	1	1.5	2.5	4	1	1.5	2	2.5
Delaware	1	2.5	4.5	7	1	2	3.5	5	1	2	2.5	4	1	1.5	2	2.5
Maryland	1	2.5	4.5	7	1	2	3.5	5	1	2	2.5	4	1	1.5	2	2.5
District of Columbia	1	2.5	4.5	6.5	1	2	3.5	5	1	1.5	2.5	4	1	1.5	2	2.5
Virginia	1.5	2.5	4.5	7	1	2	3.5	5.5	1	2	3	4	1	1.5	2	3
Mid-Atlantic	**1.1**	**2.5**	**4.5**	**6.8**	**1.0**	**2.0**	**3.5**	**5.1**	**1.0**	**1.8**	**2.6**	**4.0**	**1.0**	**1.5**	**2.0**	**2.6**
Northern Atlantic	**1.0**	**2.3**	**4.3**	**6.6**	**1.0**	**2.0**	**3.4**	**5.0**	**1.0**	**1.7**	**2.5**	**3.9**	**1.0**	**1.4**	**1.9**	**2.5**
North Carolina	1	2.5	4.5	7	1	2	3.5	5.5	1	2	3	4	1	1.5	2	2.5
South Carolina	1	2.5	4.5	7	1	2	3.5	5.5	1	1.5	2.5	4	1	1.5	2	2.5
Georgia	1	2.5	4.5	7	1	2	3.5	5.5	1	1.5	2.5	4	1	1.5	2	2.5
Florida	1	2.5	4.5	7	1	2	3.5	5	1	1.5	2.5	4	1	1	1.5	2
Southern Atlantic	**1.0**	**2.5**	**4.5**	**7.0**	**1.0**	**2.0**	**3.5**	**5.4**	**1.0**	**1.6**	**2.6**	**4.0**	**1.0**	**1.4**	**1.9**	**2.4**
Eastern U.S.	**1.0**	**2.3**	**4.3**	**6.7**	**1.0**	**2.0**	**3.4**	**5.1**	**1.0**	**1.7**	**2.6**	**3.9**	**1.0**	**1.4**	**1.9**	**2.4**

Based on these estimates, we downloaded data for 0–7 ft SLR at one-meter increments for each state and created raster stacks in Program R. Next, we used package "raster" to extract cell values within each Spotted Turtle site and then calculated the frequency of each landcover type within sites at varying levels of SLR.

To simplify results, the 12 Marsh Migration landcover categories were reduced to eight (Table 12-4). Brackish/Transition was not a landcover category identified by C-CAP and therefore was not available for 0 ft SLR (baseline). However, Marsh Migration estimated this landcover type for all other relative sea levels using elevation and tide thresholds.

Because the Marsh Migration raster tiles were restricted to coastal areas, some sites did not intersect the tiles (n=521), some only intersected cells with "background" cells (n=766), and some sites partially overlapped with landcover cells. Partially covered sites were still included in analysis. Additionally, 17 sites had landcover values from different state raster stacks. To avoid overcounting and repetition, only one state's raster stack output was preserved in results. This decision was based on which raster stack covered more site area or which raster stack had fewer background values if the site overlap was equivalent between states.

Table 12-4. The original landcover types identified by Marsh Migration, the reduced landcover types following spatial analysis, and whether the landcover type was affected by SLR.

Original	Reduced	Change with SLR?
Background	Background	No
High intensity development Medium intensity development Low intensity development Open space development	Development	
All uplands	Uplands	Yes
Palustrine forested wetland Palustrine scrub/shrub wetland Palustrine emergent wetland	Palustrine (Freshwater wetlands)	
Brackish/Transition wetland Estuarine wetland Unconsolidated shore Open water	Brackish/Transition Estuarine Unconsolidated shore Open water	

Results

Almost half of the 2,351 delineated Spotted Turtle sites in the eastern United States intersected the marsh migration layer; representing coastal areas (n=1,064; Table 12-5). Using observation-based extrapolation, it is probable that by the year 2050 sea level along the East Coast of the United States will have risen by 1 ft (Table 12-2), impacting 36% (n=379) of coastal Spotted Turtle sites (Table 12-5). While it is impossible to accurately predict SLR beyond 2050, it is likely that relative sea level will rise by at least 2 ft by 2100 (Tables 12-1, 12-3), impacting 384 Spotted Turtle sites (Table 12-5). While less likely, it is possible that sea level could rise 7 ft by 2100 (High scenario, Table 12-2) and up to 40% (n=425) of coastal Spotted Turtle sites could be impacted (Table 12-5).

Vulnerability of coastal Spotted Turtle sites to SLR appears to be highest in the Southeast and decreases with increasing latitude. Approximately 55% of coastal Spotted Turtle sites in the Southeast would be impacted by 1 ft SLR, compared to 30% in the Northeast (Table 12-5). Within the Northeast, 44% of coastal Mid-Atlantic Spotted Turtle sites could be threatened by 1 ft SLR compared to only 24% of New England coastal sites (Table 12-5). The percent of potentially impacted sites is relatively stable at 2 ft SLR but increases at 7 ft SLR with up to 62% of southeastern coastal Spotted Turtle sites affected compared to 34% in the Northeast, 49% in the Mid-Atlantic, and 27% in New England (Table 12-5).

Table 12-5. Count of total delineated Spotted Turtle sites, sites that are and are not coastal, and the number of sites within each state and sub-region that experience landcover change at different SLR.

Region	Sub-region	State	# Sites			# Coastal sites affected by SLR						
			Total	Not coastal	Coastal	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	7 ft
		CT	87	76	11	3	3	3	3	3	3	3
		MA	670	348	322	84	85	89	92	95	96	98
		ME	87	26	61	27	27	27	27	27	27	28
		NH	188	80	108	6	6	6	6	6	6	6
		RI	64	0	64	14	14	14	14	14	14	15
		VT	3	3	0	0	0	0	0	0	0	0
	New England		**1,099**	**533**	**566**	**134**	**135**	**139**	**142**	**145**	**146**	**150**
		DC	1	0	1	1	1	1	1	1	1	1
		DE	50	0	50	27	27	27	27	27	28	29
		MD	48	1	47	27	28	29	30	30	30	32
		NJ	99	31	68	14	14	14	14	14	14	14
		NY	171	161	10	6	6	6	6	6	6	6
		PA	260	251	9	0	0	0	0	0	0	0
		VA	143	53	90	47	48	49	50	52	53	54
		WV	10	10	0	0	0	0	0	0	0	0
	Mid-Atlantic		**782**	**507**	**275**	**122**	**124**	**126**	**128**	**130**	**132**	**136**
Northeast			**1,881**	**1,040**	**841**	**256**	**259**	**265**	**270**	**275**	**278**	**286**
		FL	46	33	13	8	8	9	9	9	9	9
		GA	126	105	21	14	14	14	15	16	16	17
		NC	223	84	139	85	86	87	88	88	92	93
		SC	75	25	50	16	17	18	18	18	19	20
Southeast			**470**	**247**	**223**	**123**	**125**	**128**	**130**	**131**	**136**	**139**
Total (Eastern U.S.)			**2,351**	**1,287**	**1,064**	**379**	**384**	**393**	**400**	**406**	**414**	**425**

Of the 1,064 coastal Spotted Turtle sites, 20% (n=213; Table 12-6) were selected for inclusion in the Spotted Turtle Conservation Area Network (CAN; see Chapter 14). These sites fell into three categories: Focal Core Areas, which represent regional priorities for protecting the evolutionary potential of the species; Sampling Opportunities, which are highly suitable but data-deficient sites; and Management Opportunities, which are sites where Spotted Turtles could be elevated to a management priority given their current land use and management.

Coastal Spotted Turtle sites selected for the CAN appear to be more vulnerable to the effects of SLR compared to sites that were not selected (Table 12-6). At the predicted 1 ft SLR by 2050, 49% of coastal Focal sites, 41% of Management sites, and 54% of Sampling sites could be impacted compared to 32% of unselected sites (Table 12-6). However, at the possible, but unlikely 7 ft of SLR by 2100, up to 56% of Focal sites, 41% of Management sites, and 58% of Sampling sites could be affected, as opposed to 37% of unselected sites (Table 12-6).

Table 12-6. Count of delineated Spotted Turtle sites within each site selection tier, the number of those sites that are coastal (intersect NOAA Marsh Migration layer), and the number of sites that experience landcover change at different sea level rise heights in feet, by region.

Region	Site Tier	# Sites	# Coastal sites		# Coastal sites affected by SLR						
			Total	Not affected	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	7 ft
New England	Focal	50	31	14	15	15	16	16	16	16	17
	Management	28	18	14	4	4	4	4	4	4	4
	Sampling	29	19	13	5	5	6	6	6	6	6
	Not selected	992	498	375	110	111	113	116	119	120	123
Mid-Atlantic	Focal	82	38	16	19	19	19	19	19	20	22
	Management	34	15	7	8	8	8	8	8	8	8
	Sampling	23	12	7	4	4	4	4	4	5	5
	Not selected	643	210	109	91	93	95	97	99	99	101
Southeast	Focal	46	31	14	15	15	15	15	15	16	17
	Management	20	11	5	6	6	6	6	6	6	6
	Sampling	49	38	9	28	29	29	29	29	29	29
	Not selected	355	143	56	74	75	78	80	81	85	87
Eastern U.S	Focal	178	100	44	49	49	50	50	50	52	56
	Management	82	44	26	18	18	18	18	18	18	18
	Sampling	101	69	29	37	38	39	39	39	40	40
	Not selected	1,990	851	540	275	279	286	293	299	304	311

Background and development landcover categories account for approximately 14% of the landcover within coastal Spotted Turtle sites. However, because these landcover categories do not change with increasing SLR, they were excluded from landcover change calculations. As a result, percent change in landcover may be inflated, but the patterns will remain consistent.

With increasing SLR, uplands and palustrine wetlands within coastal Spotted Turtle sites will be replaced by brackish/transition and estuarine wetlands, unconsolidated shore, and open water (Table 12-7). While primarily a freshwater species associated with palustrine wetlands, Spotted Turtles have been found in brackish environments (Agha et al. 2018). This could suggest that the transition of palustrine wetlands to brackish wetlands may not represent loss of habitat. Therefore, brackish/transition wetlands are categorized as habitat in the following summaries (e.g., Table 12-7). However, the replacement of palustrine and/or brackish wetlands with estuarine wetlands, unconsolidated shore, and open water is categorized as potential habitat loss.

Without SLR (0 ft), Spotted Turtle habitat covers approximately 95% of available area (excluding background and development) in coastal Spotted Turtle sites (Table 12-7). At the projected 1 ft SLR by 2050, around 21,000 hectares of brackish wetlands could be added to coastal Spotted Turtle sites (Table 12-7). However, despite this addition, 6% of potential habitat within coastal Spotted Turtle sites could be lost (Table 12-7). At 2 ft SLR by 2100, an additional 5% of Spotted Turtle habitat within sites could be converted to non-habitat landcover categories, and at 7 ft SLR, 20% of potential Spotted Turtle habitat could be lost (Table 12-7).

Table 12-7. Total area covered, in hectares, of Marsh Migration landcover categories across coastal Spotted Turtle sites the eastern United States under different SLR scenarios from 0- to 7ft.

	Potential Habitat			Not Habitat		
SLR	**Uplands**	**Palustrine**	**Brackish/ Transition**	**Estuarine**	**Unconsolidated shore**	**Open water**
0 ft	147,047	188,364	0	6,748	253	11,823
1 ft	141,265	153,153	21,148	15,110	2,585	20,969
2 ft	139,785	144,407	13,817	13,814	6,366	36,041
3 ft	138,390	138,135	10,218	12,617	7,587	47,284
4 ft	137,040	134,219	7,177	10,352	9,406	56,037
5 ft	135,775	131,277	5,771	8,870	10,937	61,600
6 ft	134,534	129,241	4,678	7,792	11,477	66,508
7 ft	133,228	127,711	4,011	6,815	9,804	72,661

Projected SLR-driven landcover change within coastal Spotted Turtle sites will vary by sub-region with larger habitat transitions occurring in the Southeast (Figure 12-2). At 1 ft SLR, approximately 10% of Spotted Turtle habitat (uplands, palustrine wetlands, brackish wetlands) will be lost in the Southeast while only 2% will be lost in the Northeast (Figure 12-2). Spotted Turtle sites in the Mid-Atlantic could lose up to 5% of their suitable habitat at 1 ft SLR while only 0.5% of the Spotted Turtle habitat in New England sites would transition to estuarine, shore, and open water environments (Figure 12-2).

If relative sea level were to rise by 2 ft, sites in the Southeast could lose an additional 10% of Spotted Turtle habitat cover types while the Northeast would lose an additional 1%, the Mid-Atlantic would lose an additional 3%, and New England would lose an additional 0.2% (Figure 12-2). At 7 ft SLR, 35% of the Spotted Turtle habitat within southeastern sites, 18% in Mid-Atlantic sites, 8% across Northeastern sites, and almost 2% in New England sites will have transitioned to unsuitable saline environments (Figure 12-2).

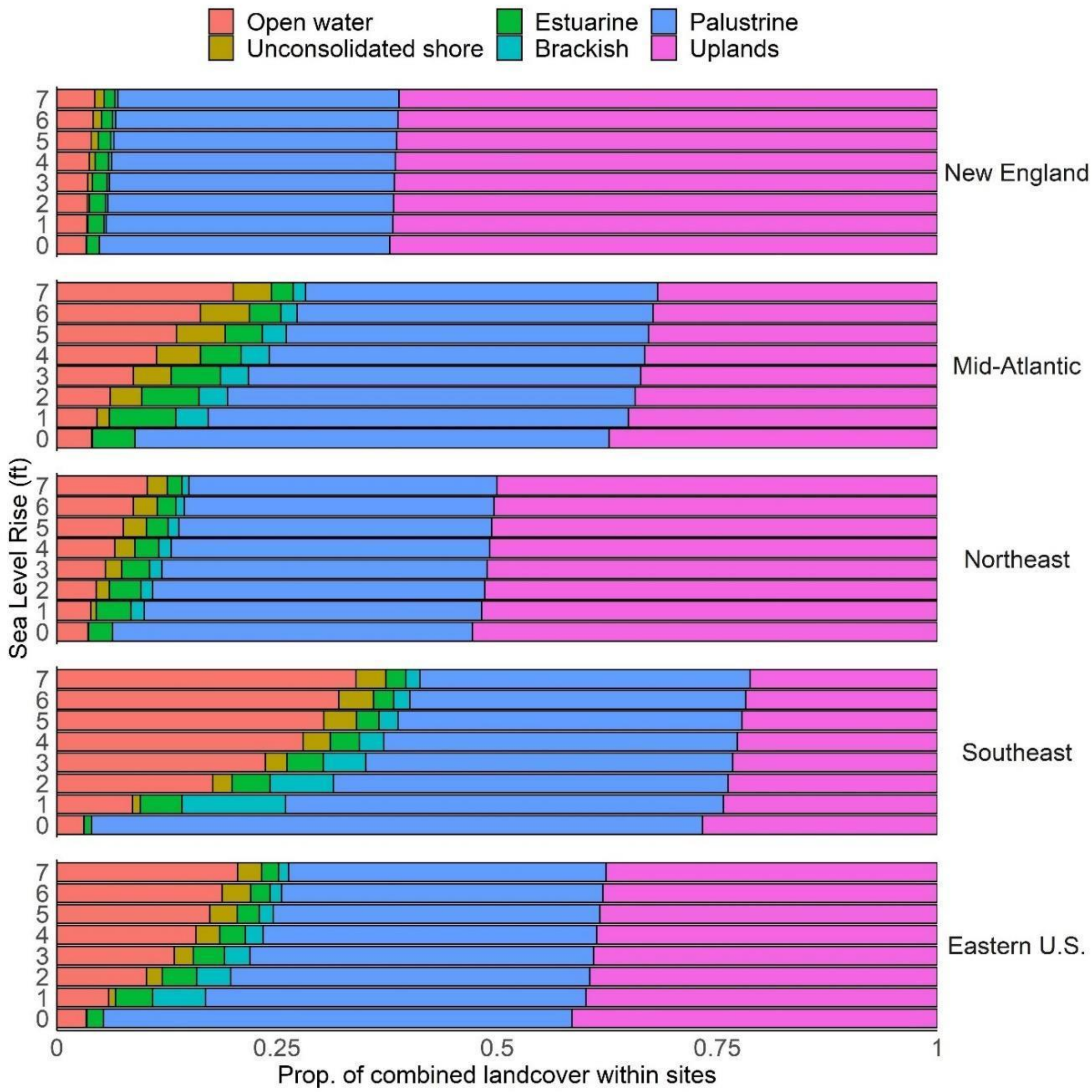


Figure 12-2. The proportion of coastal Spotted Turtle site area classified within each Marsh Migration landcover category (excluding background and development) under varying SLR scenarios from 0–7 ft, by sub-region. New England: ME, NH, MA, RI, CT; Mid-Atlantic: NY, PA, NJ, MD, DC, DE, VA; Northeast: New England & Mid-Atlantic; Southeast: NC, SC, GA, FL; Eastern U.S.: Northeast & Southeast.

Coastal Spotted Turtle sites selected for the CAN appear to be more vulnerable to SLR-driven habitat loss compared to all coastal sites (Figure 12-3). At 1 ft SLR, approximately 13% of the Spotted Turtle habitat in Sampling sites, 9.5% in Management sites, and 5% in Focal sites will be lost to estuarine marsh, unconsolidated shore, and open water (Figure 12-3). At 2 ft SLR, an additional 12% of Spotted Turtle habitat in Sampling sites, 2% in Management sites, and 6% in Focal sites will be converted to saline environments (Figure 12-3). Finally, in a worst-case-scenario of 7 ft SLR, Sampling Opportunities could lose approximately 37% of their Spotted Turtle habitat while Management Opportunities could lose 30% and Focal Core Areas could lose 23% (Figure 12-3).

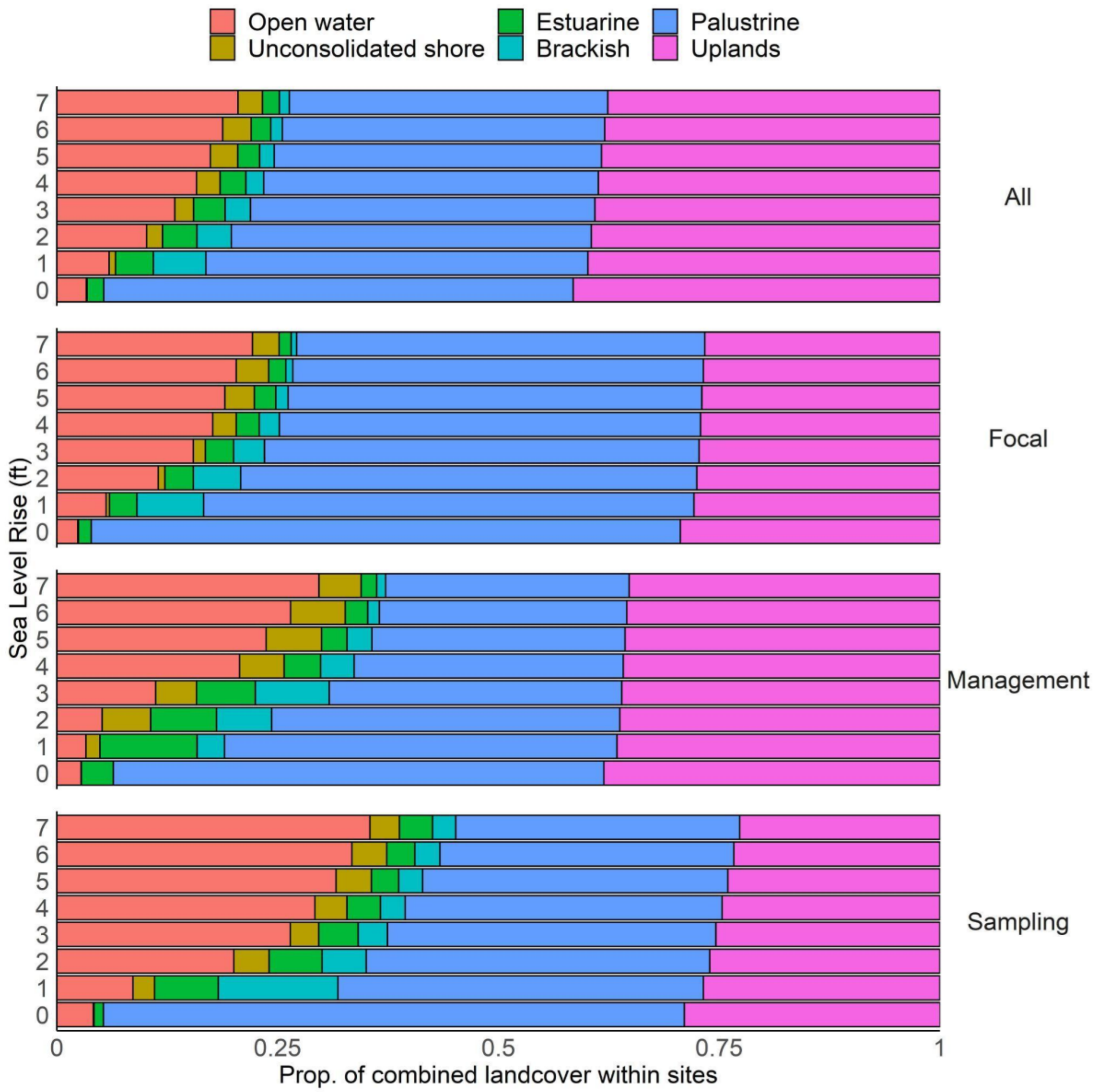


Figure 12-3. The proportion of coastal Spotted Turtle site area classified within each Marsh Migration landcover category (excluding background and development) under varying SLR scenarios from 0–7 ft, by site classification in the Conservation Area Network.

Conclusions

Given current rates of sea level rise, it is probable that relative sea level along the East Coast of the United States will rise by 1 ft in 2050. SLR projections beyond 2050 are unreliable and largely based on future greenhouse gas emissions, but it is likely that SLR along the East Coast will reach at least 2 ft by 2100 and could reach 7 ft in a high SLR scenario. Almost half of the known Spotted Turtle sites in the eastern United States are coastal (overlap NOAA's marsh migration layer) and potentially vulnerable to SLR. Increased inundation of low-lying wetlands linked to SLR will likely trigger inland migration of wetland species as low-lying areas transition to brackish and then saline environments. While Spotted Turtles inhabit brackish environments and may have a relatively high tolerance for increased salinity, they will lose habitat as SLR increases.

Our analysis suggests that with 1 ft of SLR by 2050, 6% of the Spotted Turtle habitat within coastal sites could be lost. Projected habitat loss could reach 11% by 2100 with an additional foot of SLR. Spotted Turtle sites in southeastern states are particularly vulnerable to SLR and could lose up to 10% of habitat by 2050 and 20% by 2100. Sites selected for the Spotted Turtle Conservation Area Network also appear to be especially vulnerable to SLR, particularly Sampling Priority Sites. With 1 ft of SLR by 2050, 13% of Spotted Turtle habitat within Sampling sites could be lost; and by 2100 up to 25% of habitat could be lost. However, nearly half of selected Sampling sites are in the Southeast so it is probable that their elevated risk is linked.

Focal Core Areas represent the highest priority Spotted Turtle sites across the region for the evolutionary potential of the species. Therefore, these sites and their associated Spotted Turtle habitat are considered especially valuable. While the percent of Focal Core Areas affected by SLR is higher than that across all sites, the percent of SLR-related habitat loss is not elevated. However, at 1 ft SLR, 5% of the Spotted Turtle habitat within Focal sites could be lost.

Caveats and Future Directions

Marsh Migration, used in the Spotted Turtle SLR analysis, does not incorporate future changes in coastal geomorphology or natural processes such as freshwater influences on salinity, subsidence, sediment erosion dynamics, or coastal storm impacts (NOAA Office for Coastal Management 2017). Therefore, NOAA Office for Coastal Management does not recommend its use for site-specific analysis. Additionally, future SLR is largely unknown due to the combination of Emissions and Process Uncertainty. Consequently, results from the Spotted Turtle SLR Analysis should be interpreted with caution and considered possibilities rather than predictions.

We encourage site managers to visit NOAA's Sea Level Rise Viewer (available at: https://coast.noaa.gov/slr/) and use the marsh migration tool to examine projected SLR levels for their closest Scenario Location. With this tool, land managers can examine 2022 projections for their location using different emissions scenarios, years, and with varying levels of accretion; details we were unable to incorporate for a region-wide analysis.

Additional studies at the site level to evaluate Spotted Turtle behavioral changes in coastal areas, as well as population trend analysis and site-specific vulnerability assessments to identify those high priority sites at greatest risk of effects from SLR would assist with future conservation efforts for this species. Given the combined pressures of SLR and upland development, we also suggest the prioritization of upland habitat adjacent to vulnerable high priority sites for conservation. This would help to facilitate necessary inland migration as the community structure of Spotted Turtle habitat changes with increasing inundation along the coasts.

Part V. Conservation Area Network

As part of the regional Spotted Turtle conservation planning effort supported by the Competitive State Wildlife Grants (C-SWG) and Northeast Regional Conservation Needs (RCN) programs, we delineated, attributed, scored, and selected Spotted Turtle sites for inclusion in a conservation area network (CAN). The purpose of this CAN is to identify populations and landscapes that represent priorities for Spotted Turtle conservation resources. This CAN focuses specifically on priorities for land protection, habitat management, and future sampling in data-deficient, but highly suitable landscapes. Areas identified as Focal Core Areas, represent the highest regional priorities in protecting the evolutionary potential of the species in the eastern United States. The resulting spatial data layer is intended to be used by biologists, managers, and conservationists to provide regional context, support land protection and mitigation efforts, and provide a basis for developing finer-scale conservation plans. It can also be used as a baseline to assess landscape conditions (i.e., availability of wetland habitat and landscape composition and fragmentation) within priority Spotted Turtle sites. Additional uses of the CAN are described in Part VI of this Plan. The Spotted Turtle CAN development process was based on those used for the Blanding's Turtle (Willey and Jones 2014) and the Wood Turtle (Jones et al. 2018). While this CAN was based on 11,975 Spotted Turtle records and four years of sampling data across 17 states and the District of Columbia, the full distributional extent of the species is unknown. Therefore, this CAN is designed to be updated systematically as more information is acquired within data-deficient areas such as the southern portion of the range.

Chapter 13. Site Delineation, Attribution, and Scoring

Molly K. Parren and Lisabeth L. Willey

Site Delineation: Methods

As described in Part II of this Plan, we compiled a database of 11,975 Spotted Turtle records (from Maine to Florida) gathered from multiple sources: element occurrences from each state's natural heritage program, endangered species program, and/or wildlife agency along with records from additional datasets (museum records, HerpMapper [HerpMapper 2020] personal datasets, nonprofit datasets, and federal records) and added observations from 2018–2021 region-wide standardized population assessment detailed in Part III of this Plan.

To delineate sites using this database, each Spotted Turtle record was buffered by 500 m to represent individual movement and therefore associated habitat. We then selected adjacent freshwater emergent, forested, and scrub/shrub wetlands using the National Wetlands Inventory (NWI; U.S. Fish & Wildlife Service 2020). These wetlands were then buffered by 200 m to represent potential upland habitat. We used the Department of Transportation's Highway Performance Monitoring System (HPMS) All Roads Network of Linear Referenced Data (ARNOLD, Federal

Highway Administration 2018*a*) to identify roads that represented barriers to turtle movement. We considered principal arterials such as interstates, freeways, and expressways as barriers to turtle movement, and we treated them as boundaries to a site. We also classified lower-ranking roads such as minor arterials and collectors as barriers if they had three or more lanes of traffic.

Once road barriers were identified, we then used the National Bridge Inventory (Federal Highway Administration 2018*b*) to identify any bridges that were located on a barrier road within a site that could be used as corridors by turtles between fragments of a site. If such a bridge existed, the road was not classified as a barrier. Any remaining barrier roads without bridges were then used to split sites and any site polygons that did not contain a Spotted Turtle record were removed. If a turtle record was located on a barrier road, site polygons on either side of the road were included (Figure 13-1).

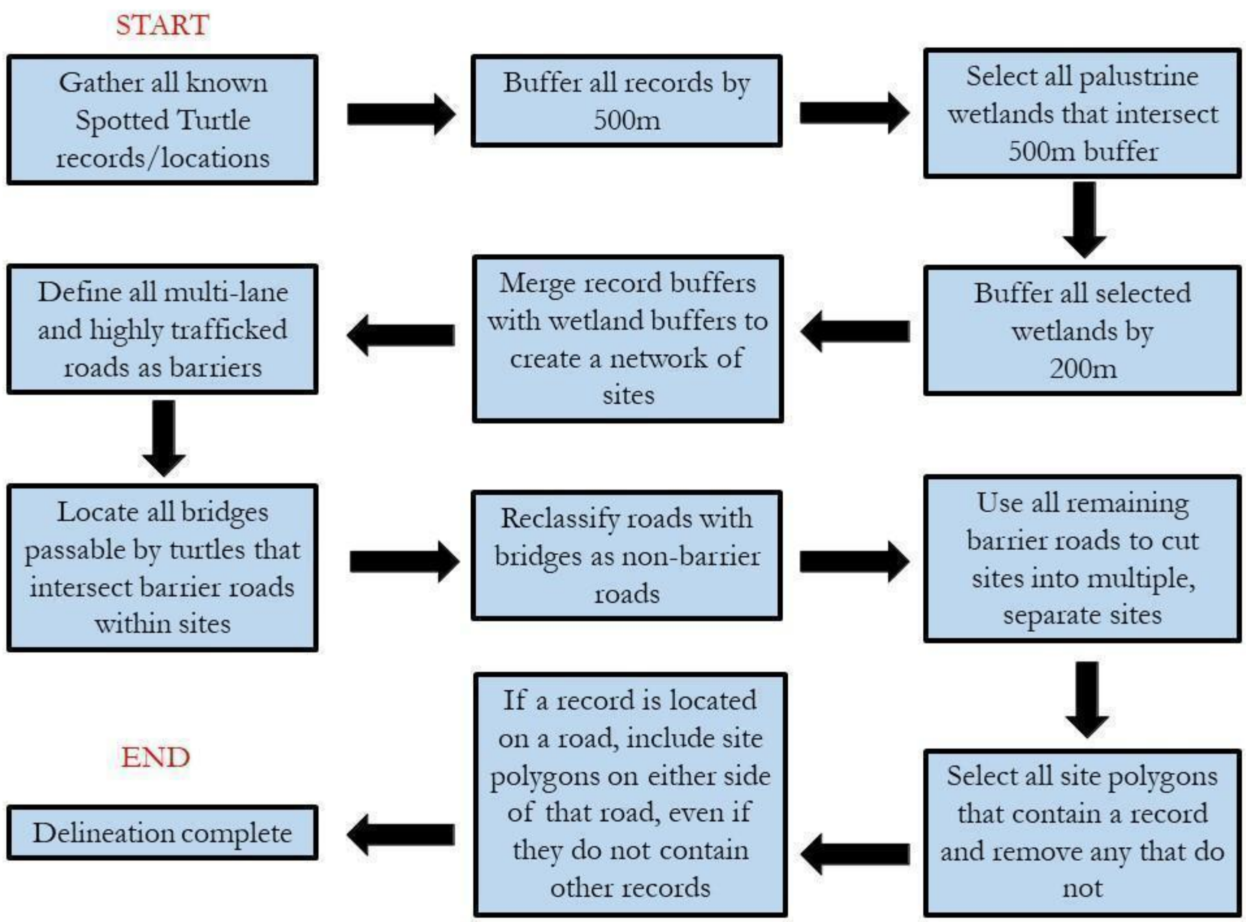


Figure 13-1. Flowchart depicting the standardized Spotted Turtle site delineation process.

Site Delineation: Results

Following the standardized site delineation process, 769,080 hectares were mapped and classified as Spotted Turtle habitat within 2,351 sites in the eastern United States (Table 13-1). Sites were delineated within 17 states and the District of Columbia, intersected five Level II ecoregions, and 17 Level III ecoregions (Table 13-1).

Table 13-1. Count, area, and percent cover of delineated Spotted Turtle sites within each geographic and political zone.

	Ecoregion/State	# Sites	Site Area (ha)	% of land area in sites
Level III Ecoregion	Acadian Plains and Hills	25	4,032	0.09%
	Atlantic Coastal Pine Barrens	142	34,530	2.41%
	Blue Ridge	12	1,743	0.04%
	Central Appalachians	1	192	0.003%
	Eastern Great Lakes Lowlands	23	12,417	0.31%
	Erie Drift Plain	14	2,975	0.1%
	Middle Atlantic Coastal Plain	340	191,727	2.44%
	North Central Appalachians	9	1,517	0.06%
	Northeastern Coastal Zone	953	250,909	5.96%
	Northern Allegheny Plateau	165	539	0.01%
	Northern Piedmont	123	18,984	0.61%
	Piedmont	43	7,781	0.05%
	Ridge and Valley	181	29,170	0.25%
	Southeastern Plains	210	107,697	0.33%
	Southern Coastal Plain	102	73,853	0.52%
	Western Allegheny Plateau	3	390	0.005%
	Northern Appalachian and Atlantic Maritime Highlands	5	29,332	0.24%
Level II Ecoregion	Atlantic Highlands	174	30,848	0.2%
	Mixed Wood Plains	1,020	270,872	0.69%
	Ozark/Ouachita-Appalachian Forests	197	31,494	0.06%
	Southeastern USA Plains	376	134,461	0.13%
	Mississippi Alluvial and Southeast USA Coastal Plains	584	300,110	0.86%
U.S. State/District	Connecticut	87	17,405	1.35%
	Delaware	50	12,497	2.4%
	Florida	46	35,680	0.24%
	Georgia	126	87,747	0.58%
	Maine	87	28,506	0.34%
	Maryland	48	12,232	0.46%
	Massachusetts	670	181,927	8.56%
	New Hampshire	188	35,943	1.5%

	Ecoregion/State	# Sites	Site Area (ha)	% of land area in sites
	New Jersey	99	31,613	1.57%
	New York	171	38,956	0.31%
	North Carolina	223	155,938	1.21%
	Pennsylvania	260	37,433	0.32%
	Rhode Island	64	13,205	4.64%
	South Carolina	75	35,714	0.44%
	Vermont	3	662	0.03%
	Virginia	143	42,046	0.4%
	District of Columbia	1	166	0.94%
	West Virginia	10	1,409	0.02%
Eastern U.S.	**Region**	**2,351**	**769,080**	**0.67%**

Site Attribution & Scoring: Methods

Following delineation, sites were attributed and scored using known habitat quality and landscape context. The relative importance of each of these factors was gauged using an expert poll.

Expert Poll

In October 2020, we sent an opinion poll to Eastern Spotted Turtle Working Group participants asking them to rate the relative importance of site attributes in determining the conservation value of a Spotted Turtle site in the eastern United States. Our definition of "conservation value" comes from the *Conservation Plan for the Wood Turtle in the Northeastern United States* (Jones et al. 2018) and refers to the "conditions necessary to sustain demographically functional and ecologically viable" Spotted Turtle populations. Responses to this poll were used to weight site criteria for delineated Spotted Turtle sites. These weights were used to develop a conservation value metric that allowed us to score sites in a standardized, repeatable manner and then use results to identify priority sites in the CAN.

We used a two-tiered hierarchical system to weight site attributes. Site criteria were divided into four site attribute classes, which were further divided into sub-metrics. This process was used to reduce the influence that correlated metrics (Figure 13-2) had on the final score of a site. The four main attribute classes were:

I. Habitat abundance and quality,
II. Within site fragmentation,
III. Surrounding landscape context,
IV. Known Spotted Turtle population,

We asked participants to rate the relative importance of each class in determining the conservation value of a site on a scale from 0 to 5 where a score of 0 = not important, 1 = somewhat important, 2 = moderately important, 3 = important, 4 = very important, 5 = most important. This same scoring criteria was then also applied to sub-metrics within each class. Additionally, we asked participants to select whether a sub-metric has a negative, neutral, or positive influence on the conservation value of a site.

Weights for each sub-metric were calculated by dividing the average score for each sub-metric by the sum of all average sub-metric values within the same class and multiplying by 100 (Jones et al. 2018). Similarly, overall class weights were calculated by dividing the average weight for each class by the overall sum of the average weights for all four classes and multiplying by 100. The directionality of a sub-metric was selected based on the majority of votes. If the majority of votes were for "neutral" influence on conservation value of a site, we selected the directionality with the next greatest number of votes.

Most metrics were calculated within the delineated boundaries of the site, with the exception of Class III (surrounding landscape context). We calculated Class III metrics for the area within three kilometers of the site boundary (including the site itself); three kilometers is equivalent to the separation distance for suitable habitat suggested by NatureServe (Van Dam et al. 2010).

We were unable to include some factors important to Spotted Turtle populations, such as nest site availability or predator abundance, because remote data for these variables were not consistently available across the region. We did include population metrics (not available for each site) for sites sampled as part of the region-wide standardized population assessment; however, these metrics were ultimately excluded from site scoring.

When the expert poll was distributed, we were considering the inclusion of two additional classes of site criteria:

V. Conservation measures
- Ownership of and access to site
- Protection of site

VI. Potential future change in habitat suitability
- Estimated change in precipitation
- Estimated change in temperature
- Estimated human development (3 km)
- Estimated development in site
- Sea level rise

Classes V and VI were the lowest ranking classes following the expert poll and the Eastern Spotted Turtle Working Group decided that the classes should be excluded in the site scoring process. Instead, sub-metrics were incorporated within site selection where characteristics like site protection could be better integrated.

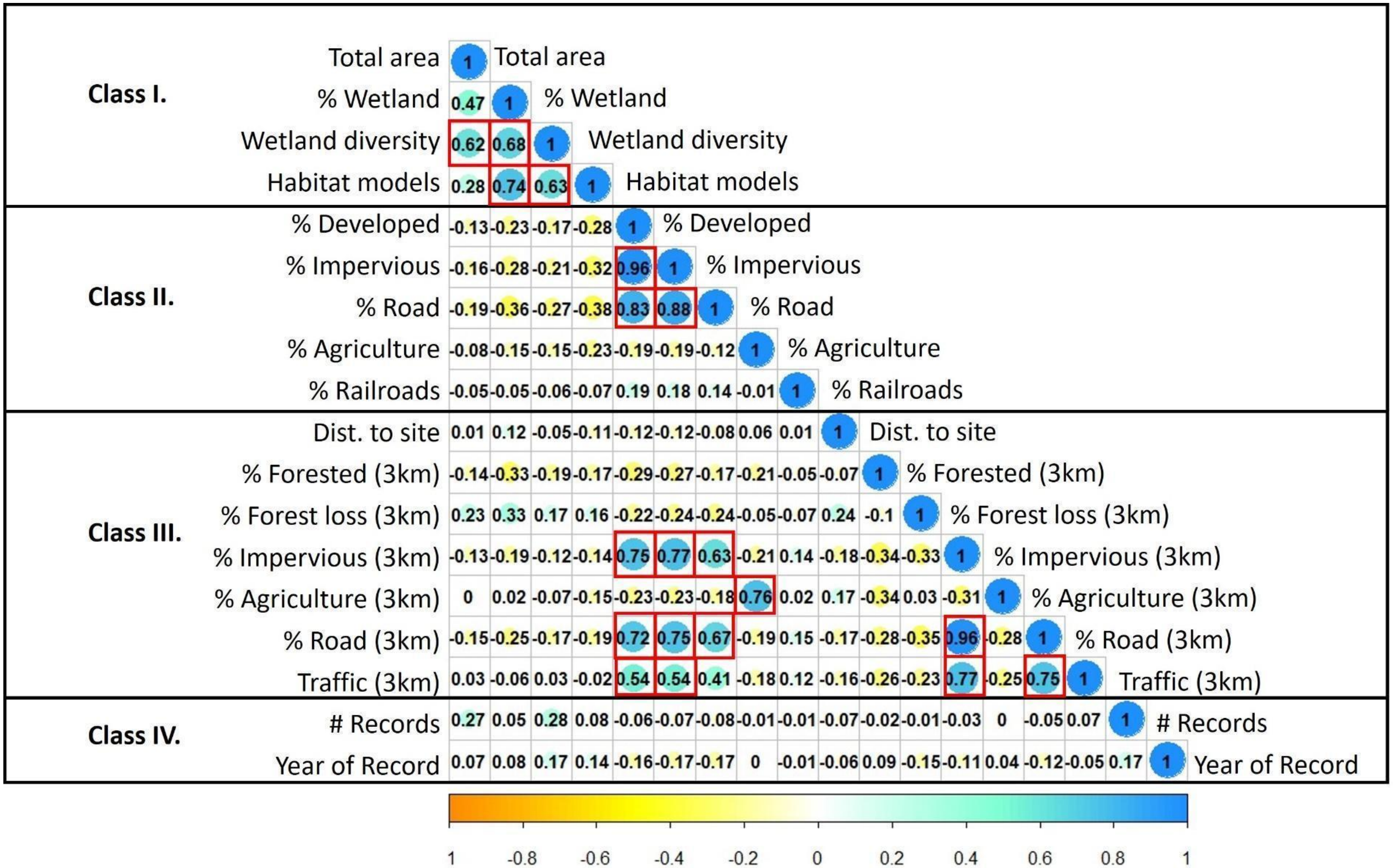


Figure 13-2. Pearson correlation coefficients for sub-metrics within 4 of the 6 classes included in the expert poll (Classes V and VI were eventually excluded from site attribution and scoring). The larger the circle in each box, the higher the correlation; the cooler the color the more positively correlated, and the warmer the color, the more negatively correlated. Red boxes represent highly correlated metrics (r ≥ 0.5).

Site Attribution and Scoring

Following the expert poll, we calculated 18 habitat characteristics (Tables 13-2, 13-3) for all delineated Spotted Turtle sites. Classes V and VI were excluded from this process following a discussion with the Eastern Spotted Turtle Working Group (see expert poll results).

We used the National Wetlands Inventory (U.S. Fish & Wildlife Service 2020) for wetland metrics, the National Landcover Database (NLCD) for developed, impervious, road, and forest cover (Dewitz 2019), Cropscape for agriculture (USDA-NASS 2019), the Department of Transportation's (DoT) Highway Performance Monitoring System (HPMS) All Roads Network Of Linear referenced Data (ARNOLD, Federal Highway Administration 2018*a*) for traffic, North American Rail Lines (Bureau of Transportation Statistics 2021) for railroads, and Global Forest Change (Hansen et al. 2013) for landscape forest loss. Two habitat suitability models were scaled and averaged to provide a single habitat modeling score for sites. One Spotted Turtle habitat suitability model was developed for this Spotted Turtle conservation plan and is detailed in Chapter 3 of this document. The other Spotted Turtle habitat model was developed for the Northeast (Compton et al. 2020) and did not extend to sites in the Southeast. Therefore, only the habitat model developed for this plan was used to calculate suitability of sites from North and South Carolina, Georgia, and Florida.

Once calculated, all site attributes (sub-metrics) were rescaled from 0–1. Because some metrics negatively influence the conservation value of a site (e.g., imperviousness within site) while others have a positive influence (e.g., number of turtle records within site), negative metrics were subtracted from one so larger values (closer to one) consistently represented a beneficial attribute to Spotted Turtles. These values were then multiplied by their respective weight and summed to produce a final score within each of the four classes. If any metric was missing for a site (typically C-SWG sampling metrics), weights were recalculated for the other metrics within the class. This was done to avoid penalizing a site for missing information. Class scores were then rescaled from 0–1, multiplied by their respective class weight, and then summed for a final overall metric for each site (Figure 13-3).

Once site scores were calculated, we performed a sensitivity analysis to identify sub-metrics or classes with outsized influence on the overall score of a site (Table 13-3). This was done to ensure that no single sub-metric or class was driving the scoring of sites but rather scores were reflective of the combination of sub-metrics and their classes. We found that Class IV. *Known Spotted Turtle Population* had the greatest influence on site score (Table 13-3), and the sub-metric: *Date of Most Recent Spotted Turtle Record* (measured in decade) had more influence than any other metric (Table 13-3). To reduce the influence of date of record on site scores we made the metric binary, so a site was either classified as historical (the most recent turtle record was from before 1990) or current (most recent record was from 1990 to 2021).

We initially included three population metrics (catch per unit of effort, sex ratio, and age structure) in site attribution and scoring for 196 sites sampled as part of the region-wide standardized population assessment. However, most sampled sites were penalized for the inclusion of the additional metrics (i.e., had a lower score when that information was included), so the metrics were ultimately excluded from site scoring.

Table 13-2. Site sub-metrics, their associated Class, description, and geospatial source if applicable.

Sub-metric	Description	Source
Class I. Habitat abundance and quality		
Total site area	In hectares	-
Wetland area	% of site that was palustrine wetland	NWI
Wetland richness	Count of palustrine wetland types within site, ranging from 0 to 81 (e.g. PFO1E: Palustrine, Forested, Broad-Leaved Deciduous, Seasonally Flooded/Saturated = 1 count)	NWI
Habitat models (avg. cell value)	Average of 2 models (if both available, or just H.P. Roberts' for southern sites) both scaled 0-1 before averaging together	B. Compton H.P. Roberts
Class II. Within site fragmentation		
Developed area	% of site classified as developed: low intensity, medium intensity, or high intensity	NLCD 2016 landcover
Impervious cover	% of site classified as impervious cover	NLCD 2016 imperviousness
Road density	% of site classified as road cover (primary, secondary, tertiary)	NLCD 2016 imperviousness
Agriculture	% of site classified as agriculture: Included row/tree crops but not cranberries or hay/pasture	Cropscape 2019
Railroads	% of site classified as railroad (converted polyline to 30m raster to mimic NLCD)	DoT N American Rail Lines
Class III. Surrounding (3 km) landscape context, including site		
Distance to site	Kilometers to nearest Spotted Turtle site	-
Forested	% of landscape classified as forested (evergreen, deciduous, mixed)	NLCD 2016 landcover
Forest loss	% permanent forest loss within landscape since 2000	Global Forest Loss
Impervious cover	% of landscape classified as impervious cover	NLCD 2016 imperviousness
Agriculture	% of landscape classified as agriculture Included row/tree crops but not cranberries or hay/pasture	Cropscape 2019
Road density	% of landscape classified as road cover (primary, secondary, tertiary)	NLCD 2016 imperviousness
Traffic	Major roads: Average Annual Daily Traffic AADT*length of roads within 3 km	DoT HPMS ARNOLD
Class IV. Known Spotted Turtle population		

Number of turtle records	Excluded all known recaptures based on turtle IDs from all data sources	All record sources
Date of most recent records	Year of record	All record sources

Table 13-3. Pearson correlation coefficients between original site score and site score when each class and sub-metric is removed from the site score calculation.

Removed metric	Correlation Coefficient
Class I. Habitat abundance and quality	**0.881**
Total site area	0.979
% Wetland cover	0.981
Wetland diversity (palustrine)	0.96
Habitat models	0.937
Class II. Within site fragmentation	**0.963**
% Development (site)	0.975
% Impervious cover (site)	0.998
% Road cover (site)	0.999
% Agriculture cover (site)	0.996
% Railroad cover (site)	0.998
Class III. Surrounding landscape context (3 km)	**0.907**
Distance to next site	0.998
% Forest cover (3 km)	0.984
% Forest loss (3 km)	0.994
% Impervious cover (3 km)	0.99
% Agriculture cover (3 km)	0.997
% Road cover (3 km)	0.994
Major road traffic (3 km)	0.997
Class IV. Known Spotted Turtle population	**0.865**
Number of records	0.918
Date of most recent record (decade)	0.857

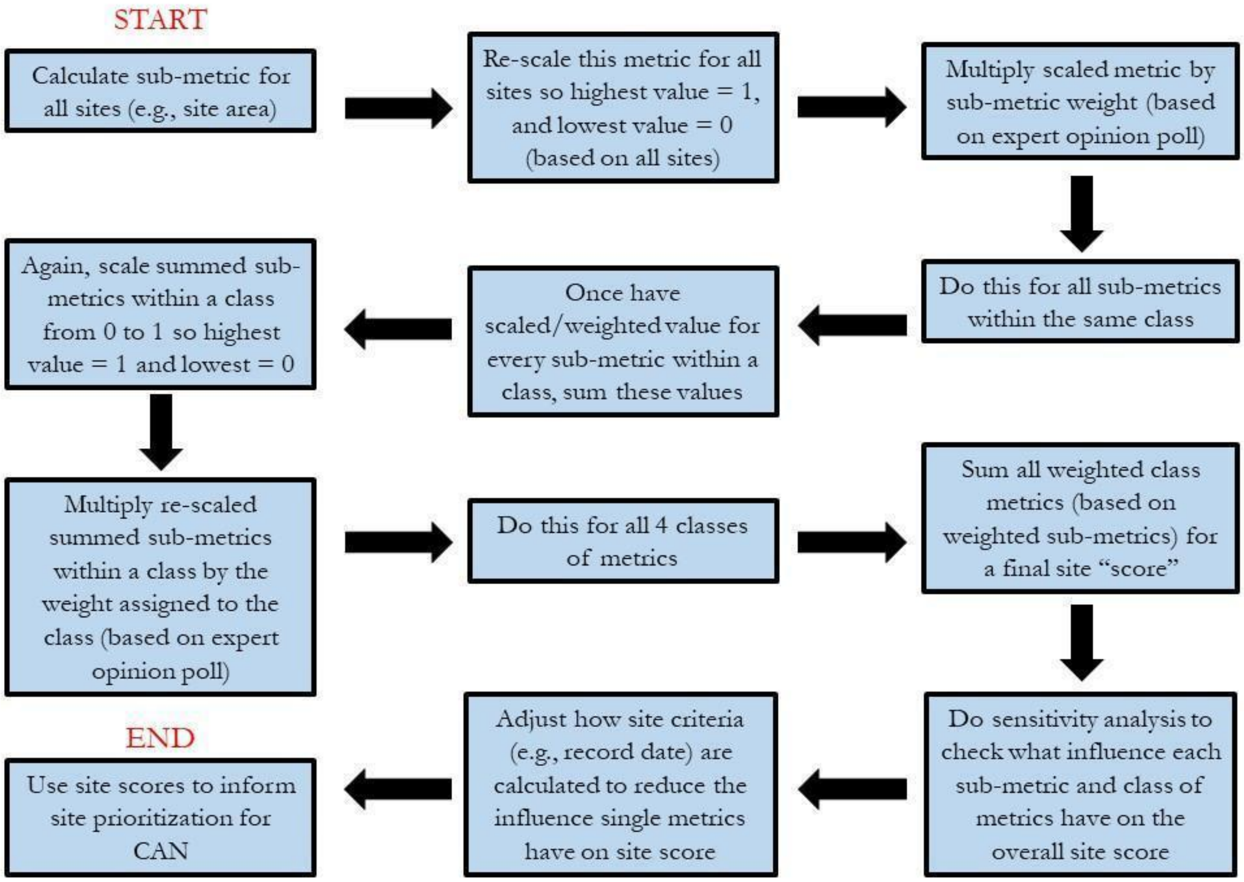
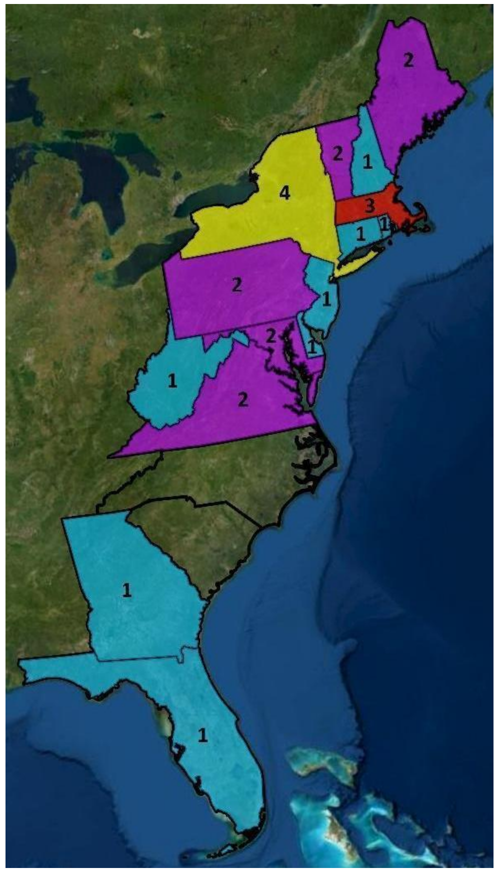


Figure 13-3. Flowchart depicting the standardized Spotted Turtle site scoring process.

Site Attribution & Scoring: Results

Expert Poll

A total of 26 respondents representing 15 states and Washington, D.C. participated in the expert poll (Map 13-1). The majority of responses came from the Northeast, and New York was the most represented state. Experts rated Class I. Habitat abundance and quality as most important to the conservation value of a site, and Class III. Surrounding landscape context, as least important (Table 13-4). The percent of development within a site was ranked as the most important sub-metric, while date of most recent record within a site was ranked least important (Table 13-5).



Map 13-1. Number of participants who took part in the expert poll within each state.

Table 13-4. The six site attribute classes in the expert poll and the associated number of votes for each importance score (0 = not important, 1 = somewhat important, 2 = moderately important, 3 = important, 4 = very important, 5 = most important), the mean importance score, and associated weight (mean/sum) for each class. Classes V and VI were ultimately excluded from site scoring, and bold weight values represent the weights without these classes.

Class	0	1	2	3	4	5	Mean	Weight
I. Habitat abundance and quality	0	0	0	3	11	12	4.36	28.12
II. Within site fragmentation	0	1	2	7	13	3	3.61	23.27
III. Surrounding landscape context (3 km)	0	1	4	7	12	2	3.43	22.12
IV. Known Spotted Turtle population	0	0	2	5	8	11	4.11	26.5

Table 13-5. Sub-metrics within the six site attribute classes and the number of votes for each importance score (0 = not important, 5 = most important) and directionality of the sub-metric (- = negative, 0 = neutral, 1 = positive; chosen direction is highlighted), the mean importance score, and associated weight (mean/sum) for each sub-metric.

Class I. Habitat abundance and quality											
	0	**1**	**2**	**3**	**4**	**5**	**-**	**0**	**+**	**Mean**	**Weight**
Total site area	0	2	3	9	7	5	1	13	12	3.36	26.04
% Wetland cover	0	1	2	5	11	7	0	3	23	3.82	29.63
Wetland diversity (palustrine)	0	1	7	10	7	1	0	7	19	3	23.27
Habitat models	1	2	9	7	5	2	0	5	21	2.72	21.06
Class II. Within site fragmentation											
	0	**1**	**2**	**3**	**4**	**5**	**-**	**0**	**+**	**Mean**	**Weight**
% Development cover	0	0	1	2	14	9	22	1	3	4.18	25.01
% Impervious cover	0	1	2	4	16	3	24	1	1	3.71	22.22
% Road cover	0	1	2	7	8	8	23	1	2	3.82	22.86
% Agriculture cover	2	0	7	13	3	1	17	9	0	2.71	16.23
% Railroad cover	2	5	7	7	5	0	20	5	1	2.29	13.68
Class III. Surrounding landscape context (3 km)											
	0	**1**	**2**	**3**	**4**	**5**	**-**	**0**	**+**	**Mean**	**Weight**
Dist. to next site	0	2	3	8	8	5	19	0	7	3.45	14.57
% Forest cover (3 km)	0	1	3	6	11	5	0	2	24	3.64	15.4
% Forest loss (3 km)	1	0	6	12	7	0	20	4	2	2.93	12.38
% Impervious cover (3 km)	0	1	4	6	11	4	24	1	1	3.53	14.94
% Agriculture cover (3 km)	3	2	7	10	3	1	18	8	0	2.46	10.41
% Road cover (3 km)	0	2	0	5	11	7	22	2	2	3.85	16.28
Major Road Traffic (3 km)	0	2	2	4	10	8	22	3	1	3.79	16
Class IV. Known Spotted Turtle population											
	0	**1**	**2**	**3**	**4**	**5**	**-**	**0**	**+**	**Mean**	**Weight**
Catch per unit of effort (CPUE)	0	0	2	2	13	9	1	0	25	4.11	25.85
Age structure	0	1	1	6	13	5	1	5	20	3.79	23.82
Sex ratio	0	4	4	12	6	0	1	6	19	2.79	17.52
Number of records within site	0	4	5	8	6	3	0	6	20	2.96	18.65
Date of most recent record in site	1	7	8	6	2	2	1	10	15	2.25	14.16

Site Attribution and Scoring

Final site scores ranged from 5.8 to 81.18 and the average site score was 48.79 (Figures 13-4, 13-5). An analysis comparing current and historical sites and their associated mean attribute values is available in Part IV. Threats and Status of the Spotted Turtle. Figure 13-6 shows average values for each class metric across the eastern United States, by state, level II ecoregion, and level III ecoregion, prior to rescaling. The average score for all Spotted Turtle sites was 4.56 for Class I, 19.88 for Class II, 15.23 for Class III, and 9.13 for Class IV (Figure 13-6). Table 13-6 shows the average site attribute value within each class for all delineated Spotted Turtle sites in the eastern United States.

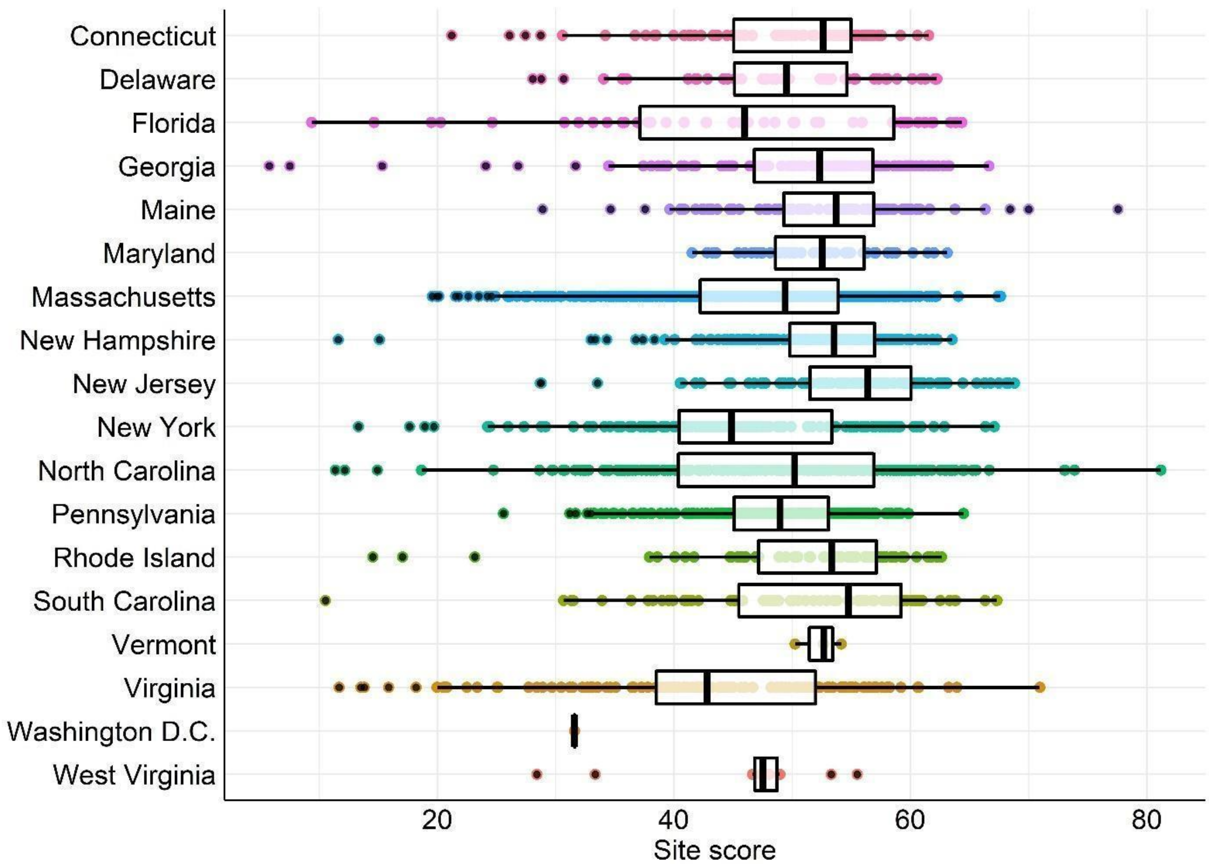


Figure 13-4. Box plot and associated site scores (points) for each site, by state.

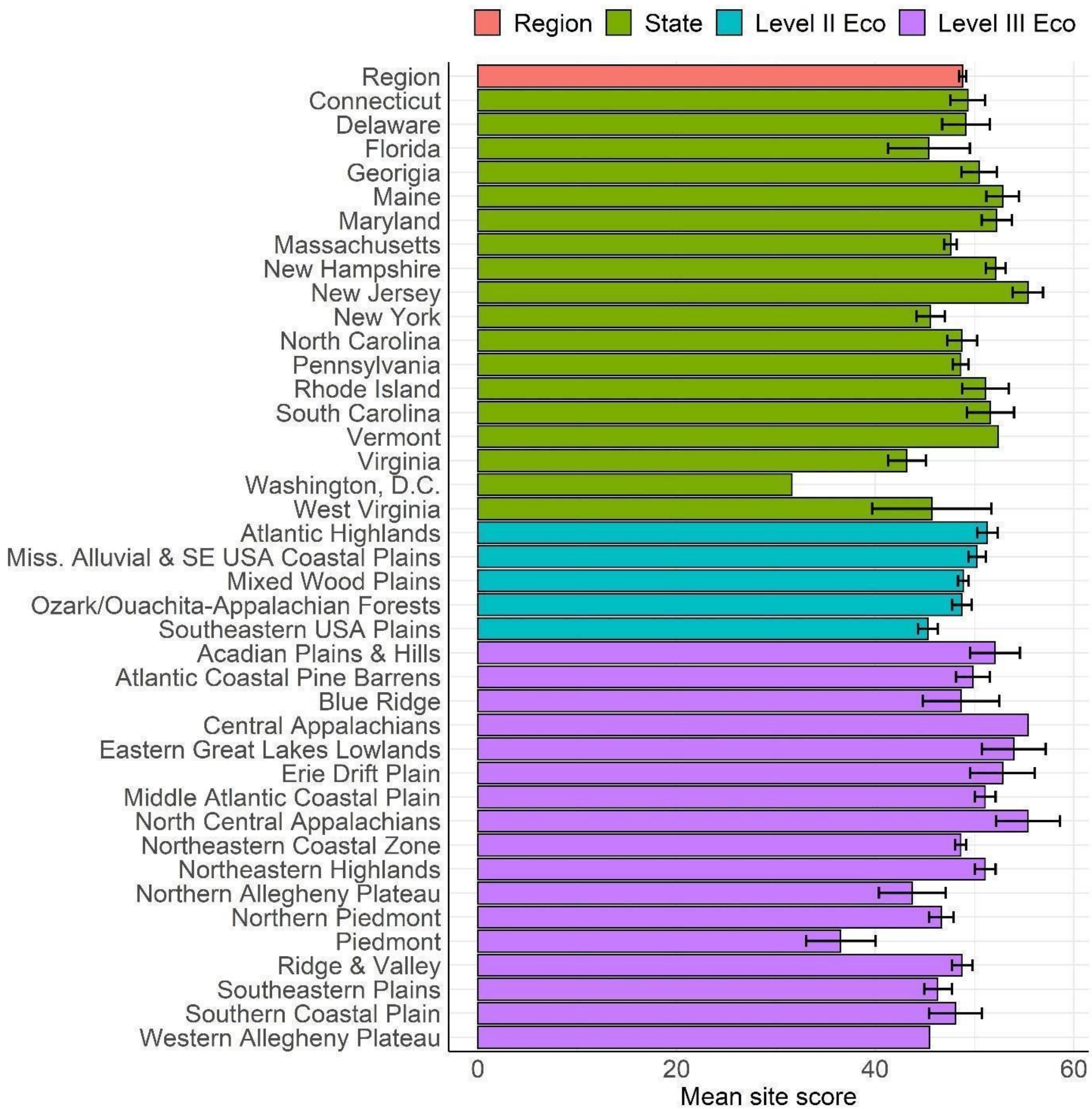


Figure 13-5. Average Spotted Turtle site score by geographic and political boundaries. Confidence intervals not shown for areas with fewer than 5 sites. Region represents the eastern United States.

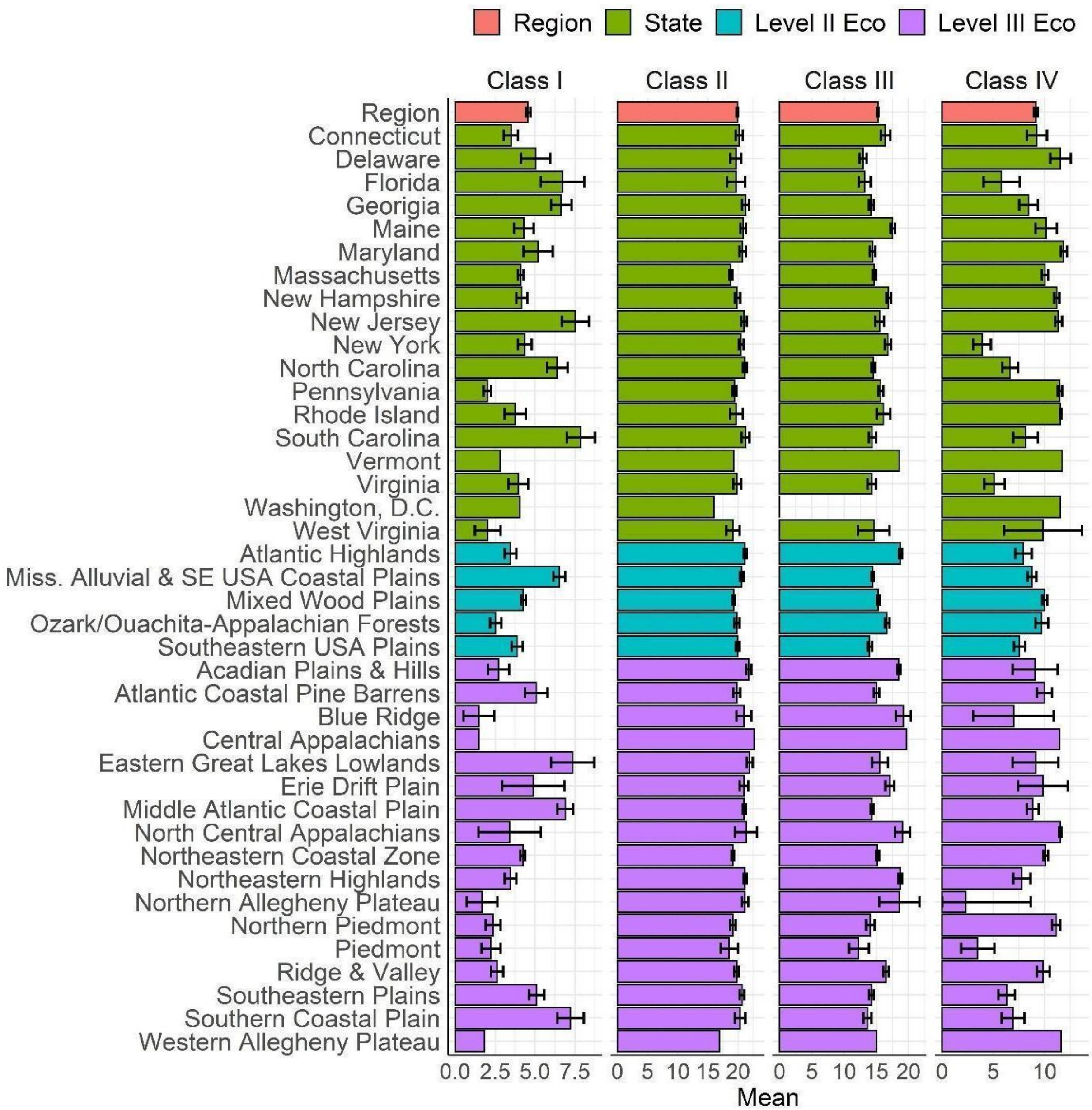


Figure 13-6. Class scores by geographic and political borders. Class I. Habitat abundance and quality, Class II. Within site fragmentation, Class III. Surrounding landscape context (3 km), Class IV. Known Spotted Turtle population. Scales differ by class (x axis). Region represents the eastern United States.

Table 13-6. Site attributes and their mean value and standard error (SE) across all delineated Spotted Turtle sites in the eastern United States (n=2,351).

Class	Attribute	Mean	SE
Class I. Habitat abundance and quality	Site area (ha)	327.50	14.32
	% Wetland	19.63	0.39
	Wetland types	8.56	0.16
	HPR model	168.89	1.72
	BC model	56.10	1.24
	Models (both)	0.22	0.003
Class II. Within site fragmentation	% Developed	9.02	0.29
	% Impervious	16.24	0.39
	% Road	8.17	0.14
	% Agriculture	7.99	0.27
	% Railroad	0.33	0.02
Class III. Surrounding landscape context (3 km)	Dist. to site (km)	3.84	0.12
	% Forest	42.42	0.43
	% Forest loss	6.98	0.22
	% Impervious	18.97	0.37
	% Agriculture	9.84	0.25
	% Road	9.24	0.13
	Traffic	424,320,199.28	12,569,151.56
Class IV. Known Spotted Turtle population	# Records	5.17	0.38
	Record year	2003.76	0.35

Chapter 14. Site Selection and Conservation Area Network Tiers

Molly K. Parren and Lisabeth L. Willey

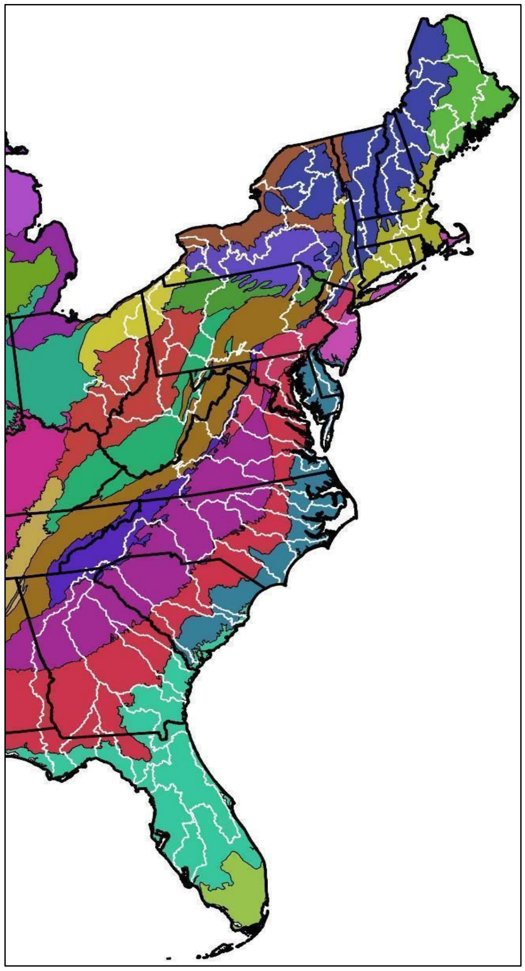
Methods

The final step of the Conservation Area Network (CAN) development process involved site selection. Sites were selected for inclusion in the CAN using three different tiers: Focal Core Areas, Sampling Opportunities, and Management Opportunities.

Focal Core Areas

Focal Core Areas were selected to meet three core principles of species conservation: representation, resiliency, and redundancy (Shaffer and Stein 2000). Representation describes a species' ability to adapt to a changing environment over time (diversity), resiliency describes its ability to withstand stochastic disturbance (demographic factors), and redundancy describes its ability to withstand catastrophic events (distribution, Smith et al. 2018). Through these Focal Core Area selections, we aim to create a network of resilient, healthy, genetically robust, demographically and ecologically self-sustaining populations of Spotted Turtles that are distributed across their historical range in ecologically representative settings (Redford et al. 2011).

The primary selection criteria for Focal Core Areas focused on representation and redundancy by selecting the top two scoring sites at multiple geographic and political levels (Figure 14-1; Table 14-1; Map 1): the top two sites in the eastern United States, in each state, in each Level III EPA Ecoregion, and in each major watershed (HUC 4 subregion in the North and HUC6 basin in the South to account for the fact that northern states are smaller and therefore were overly selected at the state level). If the top site within any selection category was already included based on previous criteria, the next best site was selected.



Map 14-1. Geographic levels used for Spotted Turtle site selection: Level III ecoregions (in color), northern HUC4: subregions and southern HUC6: basins (white outlines), and states (black outline).

Secondary selection criteria for Focal Core Areas focused on representation and resiliency by selecting isolated (island) populations and populations with large known abundances (Figure 14-1; Table 14-1), based on catch per unit effort (CPUE: turtle captures/trap checks) during regional standardized sampling in the 75th percentile (≥0.18 CPUE) or greater number of Spotted Turtle records in the 98th percentile or better (≥43 records). Islands provide unique ecological and adaptive contexts, including uncommon competitor and predator assemblages, but are difficult to directly compare to mainland landscape contexts. We plan to include genetically distinct sites within Focal Core Areas once genetic information is available.

Sampling Opportunities

For a site to be considered a Focal Core Area it had to be current (had a Spotted Turtle record within the past 30 years) and contain more than one record. If the only site within an ecoregion, subregion, or basin was historical and/or only had one record, the site was selected as a Sampling Opportunities. Sampling Opportunities were selected to fill information gaps in what is currently known about the distribution and robustness of Spotted Turtle populations throughout the eastern

United States. These were sites that scored or modeled well, suggesting that they contained high quality habitat, but were not sampled in the recent regional population assessment.

Specifically, sites were selected as Sampling Opportunities if they were current, had multiple Spotted Turtle records, were not recently sampled and either (1) had a site score within in the top 25% of all sites (≥ 55 site score), (2) significantly overlapped (≥45% cover overlap) a Spotted Turtle conservation core in the Northeast, as defined by Compton et al. (2020), or (3) had a high habitat model score within the top 25% of sites in the Southeast (≥ 215 habitat model score; Figure 14-1; Table 14-1). Additionally, 61% of the 2,351 delineated Spotted Turtle sites in the eastern United States contained only a single record, precluding selection as a Focal Core Area. Therefore, we selected any current sites based on a single record that were not sampled in the regional population assessment and that were high scoring (in the 95th percentile, ≥ 61 site score) as Sampling Opportunities (Figure 14-1; Table 14-1).

Management Opportunities

Management Opportunities were selected from the remaining unselected sites that were current and contained multiple Spotted Turtle records. These sites were selected to represent areas where Spotted Turtles could be elevated to a management priority given current land use and management. Management sites fell into three main categories: Agricultural Mitigation Sites, Protected Sites, and Supporting Sites.

Sites that were large (≥ 328 ha), high scoring (≥ 55 site score), with high agricultural cover (≥ 8%), and low road cover (≤8.2%) were selected as Agricultural Mitigation Sites (Figure 14-1; Table 14-1). These sites represent high quality Spotted Turtle habitat where the risk of road mortality is low but Spotted Turtles may be negatively impacted by agricultural practices. These are areas where programs such as the Natural Resources Conservation Science (NRCS) Working Lands for Wildlife could be effective in enhancing Spotted Turtle habitat on working lands.

Sites that were high scoring (≥55 site score) and overlapped protected lands that were either federal or state property (vs. local) were selected as Protected Sites (Figure 14-1; Table 14-1). We used the Protected Areas Database of the United States (PAD-US; U.S. Geological Survey GAP Analysis Project 2018) to identify protected land within delineated Spotted Turtle sites. Of the 2,351 delineated sites, 1,763 intersected protected lands in some way. However, protected lands fall under a variety of categories with varying levels of protection. The United States Geological Survey's GAP Analysis Project (GAP; U.S. Geological Survey GAP Analysis Project 2018) classifies protected lands into four statuses:

GAP 1: Areas that are permanently protected from conversion of natural land cover with a mandated management plan within which disturbance events proceed or are mimicked (managed for biodiversity).

GAP 2: Areas that are permanently protected from conversion of natural land cover with a mandated management plan within which disturbance events can be suppressed (managed for biodiversity).

GAP 3: Areas where the majority of the land is permanently protected from conversion of natural land cover but are subject to extractive uses of either a broad, low-intensity type (e.g., logging, Off Highway Vehicle recreation) or localized intense type (e.g., mining). Protection for federally listed endangered and threatened species is granted throughout the area (managed for multiple uses).

GAP 4: No known mandate held by managing entity to prevent conversion of natural cover (no known biodiversity protection).

We did not limit Protected Site selection to a specific GAP status because some federal managers such as the Department of Defense (DoD) and Natural Resources Conservation Service (NRCS) manage lands that are classified as GAP 4. Instead, Protected Site selection considered a variety of criteria including: the number of sites already selected within the state, the protected lands manager, year of most recent Spotted Turtle record, percent of site that was protected, impervious cover within site, and protected lands designation, and GAP status. Table 14-2 summarizes the number of sites selected by manager, designation, and GAP status. Because some sites had multiple protected lands within their boundaries, the total number of sites in Table 14-2 exceeds the number of total sites selected within the protected sites category.

Finally, we utilized expert opinion to include additional Supporting Sites that local experts think are crucial to the CAN and were not selected using any other criteria (Figure 14-1; Table 14-1). Because site selections were primarily based on remotely collected data (e.g., national geospatial layers), which can be limiting, state partners were given the opportunity to change the selection status of all sites in their state given their expert opinion.

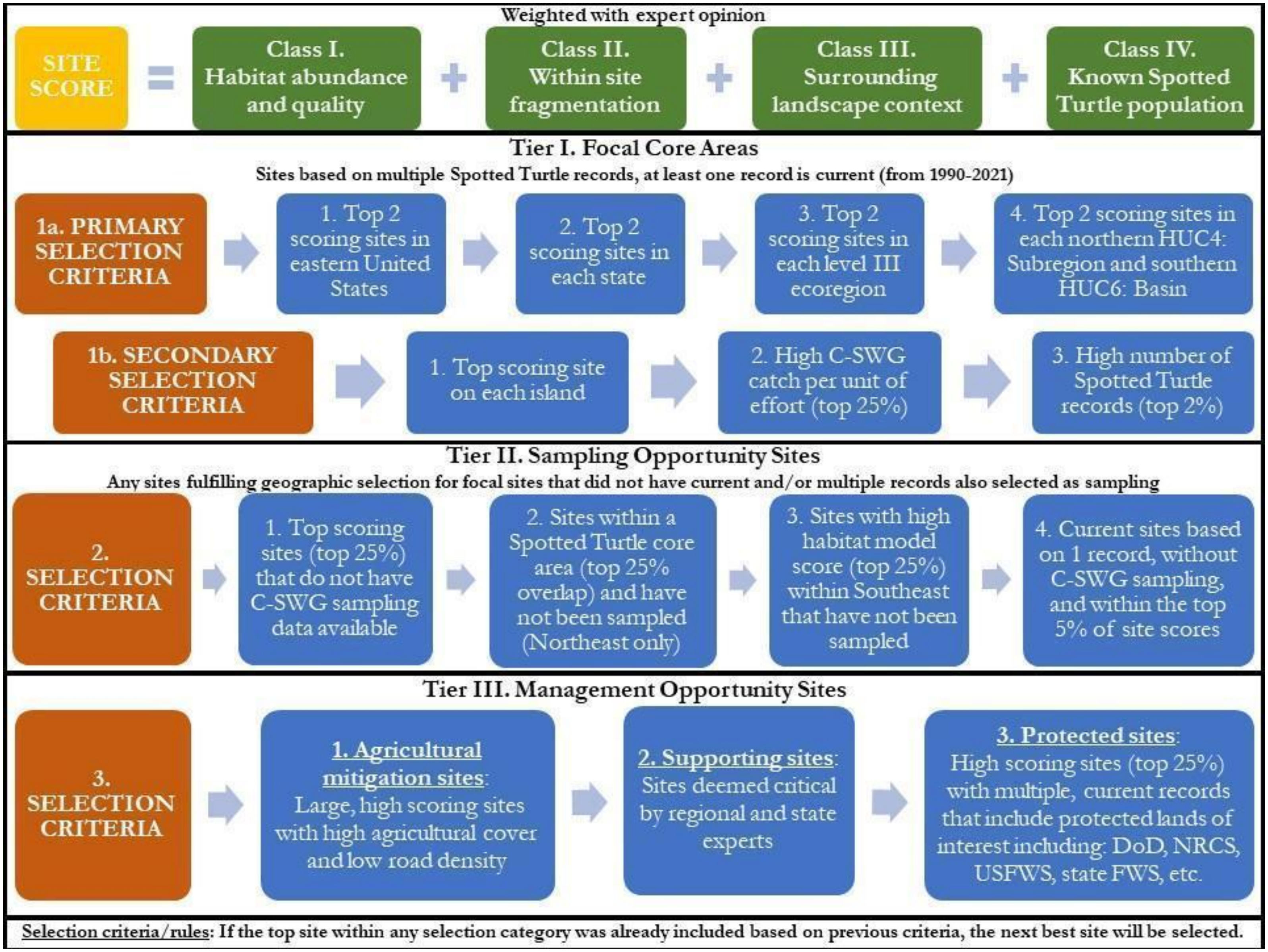


Figure 14-1. Flowchart depicting the standardized Spotted Turtle site selection process.

Results

Of the 2,351 Spotted Turtle sites delineated, attributed, and scored in the eastern United States, 15% were selected for the CAN (Table 14-1), representing 39% of all delineated habitat (Table 14-3). Focal Core Areas made up 8% of all sites and 25% of delineated habitat, sampling opportunities accounted for 4% of all sites and 6% of delineated habitat, and management opportunities represented 3% of all sites and 8.5% of delineated habitat (Table 14-1).

Table 14-1. Site selection tiers, their sub-selection identifiers, descriptions of selection criteria, including number of sites selected for inclusion in the Conservation Area Network.

Requirement	Selection Criteria	# Sites
	Focal Core Areas	**178**
Current site with multiple records	Top 2 scoring sites in eastern U.S.	2
	Top 2 scoring sites in each state	35
	Top 2 scoring sites in level III ecoregion	31
	Top 2 scoring sites in northern HUC4: Subregions and southern HUC6: Basin	35 33
	Top scoring sites on each island	6
	High (75th percentile: 0.18) C-SWG CPUE	25
	High (98th percentile: 43) number of Spotted Turtle records	11
	Sampling	**101**
Single and/or historical record	Top in level III ecoregion	2
	Top in northern HUC4: Subregions	8
	Top in southern HUC6: Basins	10
	Top on island	8
Current sites not sampled in regional population assessment (C-SWG)	Top (75th percentile: 55) scoring sites	14
	Northeast: High (75th percentile: 45%) percent overlap with mapped Spotted Turtle core	10
	Southeast: High (75th percentile: 215) habitat model score	20
	High (95th percentile: 61) scoring sites based on 1 record	29
	Management	**82**
Current site with multiple records	Large (328 ha), high scoring (50) sites with high agricultural cover (8%) and low road cover (8.2%, 50th percentiles used)	29
	Sites deemed critical by experts	
	Top (75th percentile: 55) scoring sites that include protected lands	53
	Total	**361**

Table 14-2. The number of selected Management Opportunities within each GAP status code by protected lands designation and manager. DoD: Dept. of Defense, USFWS: U.S. Fish & Wildlife Service, NPS: National Park Service, NRCS: Natural Resources Conservation Service, SDNR: State Dept. of Natural Resources, SDC: State Dept. of Conservation, SPR: State Park and Recreation, SFW: State Fish and Wildlife. Multiple protected land designations could be within one site.

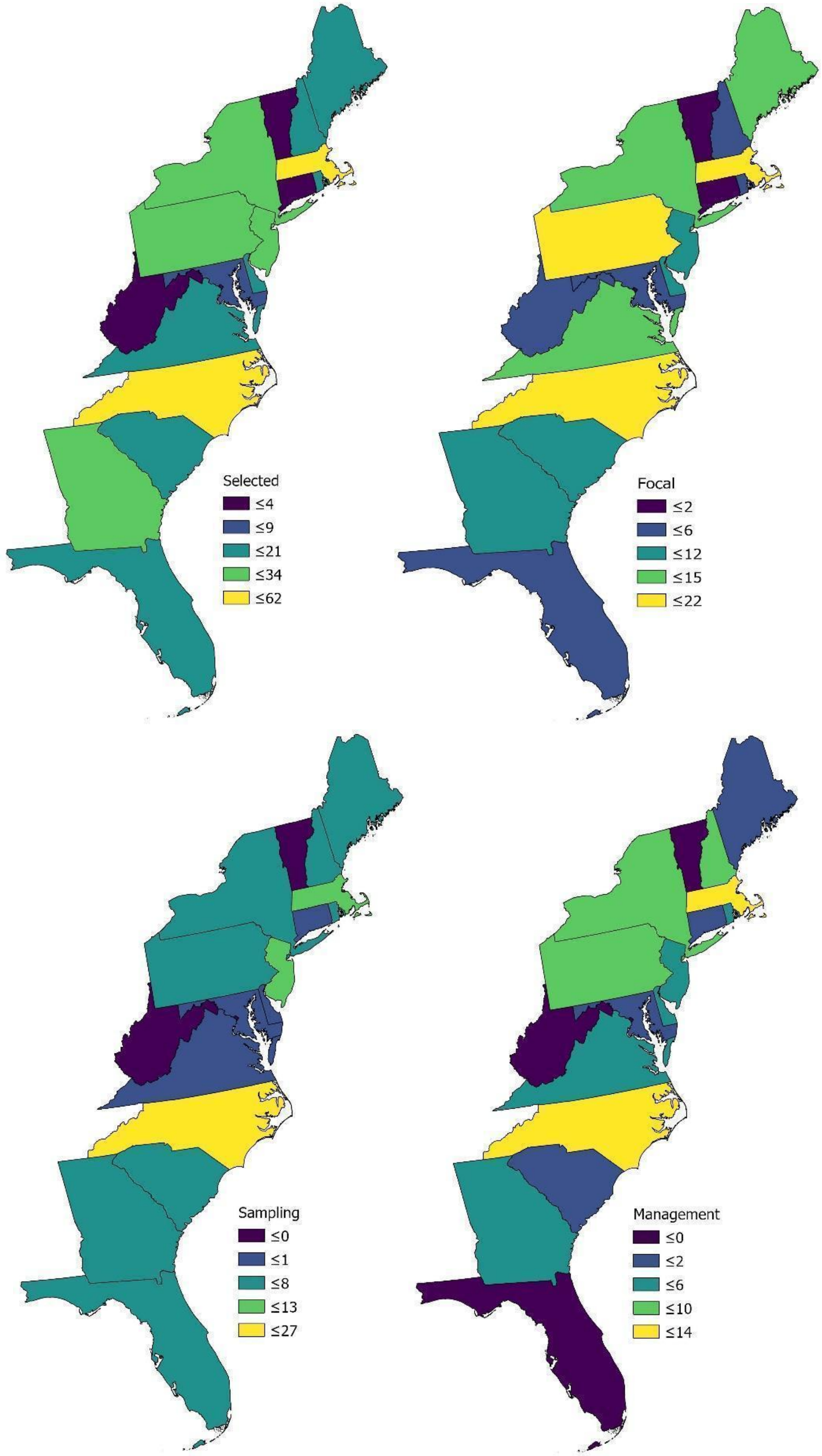
Manager	Designation	Gap 1 sites	Gap 2 sites	Gap 3 sites	Gap 4 sites	Total sites
DoD	Military Land	0	0	0	7	7
USFWS	Conservation Easement	0	1	1	2	4
USFWS	Marine Protected Area	0	4	0	0	4
USFWS	National Wildlife Refuge	0	7	0	0	7
USFWS	Unknown Easement	0	0	0	1	1
NPS	Marine Protected Area	0	2	0	0	2
NPS	National Lakeshore or Seashore	0	2	0	0	2
NPS	National Recreation Area	0	0	2	0	2
NRCS	Agricultural Easement	0	0	0	1	1
NRCS	Conservation Easement	0	8	0	0	8
NRCS	Unknown Easement	0	0	2	0	2
SDC	State Conservation Area	2	1	0	0	3
SDC	State Park	0	1	0	0	1
SDC	State Resource Management Area	0	0	2	0	2
SDNR	State Resource Management Area	0	0	1	0	1
SDNR	State Conservation Area	0	2	2	0	4
SDNR	State Park	0	0	1	0	1
SDNR	State Resource Management Area	0	0	13	0	13
SFW	State Conservation Area	0	7	7	0	14
SFW	State Other or Unknown	0	0	0	1	1
SFW	State Resource Management Area	0	0	4	0	4
SPR	State Park	0	1	0	1	2
SPR	State Resource Management Area	0	0	2	0	2

Massachusetts and North Carolina were the two states with the most sites selected overall, and by category (Table 14-3; Map 14-2). Massachusetts had the highest number of Focal Core Areas while North Carolina had the highest number of Sampling, Management, and overall selected sites (Table 14-3; Map 14-2). However, Massachusetts has the greatest number of delineated sites, likely due to large sampling effort in the state, and only 7% of sites in that state were selected for the CAN, the smallest proportion of any state, with the exception of Connecticut, but because there are so many delineated sites in Massachusetts, it still had more sites selected than any state except North Carolina. North Carolina also had the largest area selected overall, and within each selection tier

(Table 14-3), but aside from Massachusetts it has the largest amount of delineated habitat, and apart from Georgia, the highest habitat suitability score. In general, Spotted Turtle sites were larger in the Southeast (663 ha) compared to the Northeast (240 ha) likely due to a combination of greater wetland extent in the south and greater fragmentation by roads in northern states. In addition, the northeastern states tended to have a higher density of records (and therefore delineated sites) compared to the southeastern states, likely due to sampling effort and record tracking, rather than reflecting habitat suitability.

Table 14-3. Count (Sites) and area in hectares (ha) of all delineated Spotted Turtle sites, selected sites (total), and selected sites by Tier (Focal, Sampling, Management) within each state.

State	Delineated		Selected							
			Focal		Sampling		Management		Total	
	Sites	ha	Sites	ha	Sites	ha	Sites	ha	Sites	ha
CT	87	17,405	2	381	1	207	1	290	4	879
DC	1	166	1	235	0	0	0	0	1	235
DE	50	12,497	10	4,858	1	332	5	2,079	16	7,269
FL	46	35,680	6	13,468	8	9,936	0	0	14	23,405
GA	126	87,747	11	17,355	8	10,513	5	7,375	24	35,243
MA	670	181,927	22	23,392	13	5,761	13	8,587	48	37,740
MD	48	12,232	6	3,524	1	331	2	862	9	4,717
ME	87	28,506	15	15,407	5	1,317	1	171	21	16,896
NC	223	155,938	21	58,366	27	19,081	14	10,950	62	88,397
NH	188	35,943	4	1,769	4	2,101	8	2,877	16	6,747
NJ	99	31,613	12	10,170	10	3,943	6	2,899	28	17,013
NY	171	38,956	15	7,731	6	2,622	7	2,946	28	13,299
PA	260	37,433	20	4,578	4	882	10	2,771	34	8,231
RI	64	13,205	5	3,128	6	1,282	5	1,448	16	5,858
SC	75	35,714	8	8,723	6	6,499	1	600	15	15,822
VA	143	42,046	14	14,669	1	499	4	2,792	19	17,960
VT	3	662	2	566	0	0	0	0	2	566
WV	10	1,409	4	708	0	0	0	0	4	708
Eastern U.S.	**2,351**	**769,080**	**178**	**189,027**	**101**	**65,309**	**82**	**46,649**	**361**	**300,985**



Map 14-2. Number of delineated Spotted Turtle sites selected overall and within each selection tier by state.

The average site score for all selected sites was 57.77 (+/- 0.36), while the average site score for all sites (including those not selected) was 48.79 (+/- 0.19; Table 14-4). Of the selected sites, Focal sites had the highest average site score (Table 14-4). Figure 14-2 displays the average percent cover of a variety of landcover types within selected and unselected sites.

Table 14-4. Mean attribute values for all sites, unselected sites, total selected sites, Focal sites, Management sites, and Sampling sites. The number of sites within each category and their average score is also provided.

Attribute	All sites	Unselected sites	Selected sites	Focal sites	Management sites	Sampling sites
# Sites	2,351	1,990	361	178	82	101
Site score	48.79	47.16	57.77	58.98	56.77	56.44
Area (ha)	327.50	235.66	833.75	1,061.9 5	568.89	646.63
% Wetland	19.63	16.46	37.14	35.82	30.45	44.88
Wetland types	8.56	7.17	16.25	18.49	13.24	14.74
Model 1 (HPR)	168.53	158.55	223.58	222.70	202.48	242.25
Model 2 (BC)	44.91	41.83	61.91	66.67	50.06	63.15
% Developed	9.02	10.14	2.85	3.03	1.94	3.27
% Impervious	16.24	18.01	6.47	6.87	5.34	6.69
% Road	8.17	8.88	4.28	4.20	4.14	4.53
% Agriculture	7.99	8.53	4.98	4.64	7.87	3.23
% Railroad	0.33	0.36	0.20	0.29	0.09	0.14
Dist. to site	3.84	3.62	5.08	4.79	2.92	7.33
% Forested (3km)	42.42	42.77	40.46	42.10	44.42	34.37
% Forest loss (3km)	6.98	6.60	9.06	8.38	8.51	10.70
% Impervious (3km)	18.97	20.40	11.06	12.00	9.26	10.85
% Agriculture (3km)	9.84	9.97	9.09	8.46	12.22	7.66
% Road (3km)	9.24	9.80	6.16	6.50	5.68	5.94
Traffic/10^8 (3km)	4.065	4.275	2.904	3.616	1.825	2.524
CPUE	0.17	0.15	0.19	0.23	0.06	0.01
% Juvenile	22.25	24.11	22.01	22.54	16.76	0
Dist. from 0.50 male	0.11	0.08	0.12	0.11	0.14	0
Records	5.17	2.38	20.52	36.23	7.87	3.10
Year	2004	2002	2012	2016	2013	2006

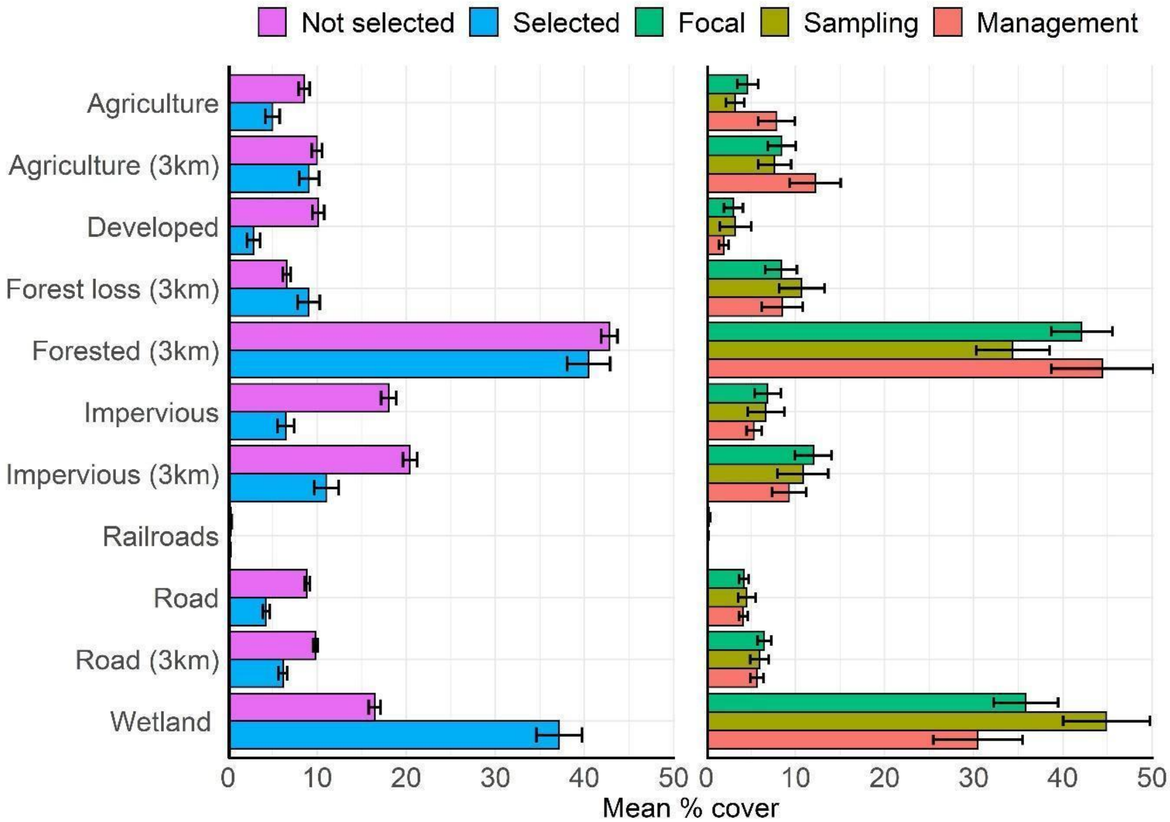


Figure 14-2. Mean percent cover for site metrics at unselected sites, and selected sites (left) and selected Focal sites, Sampling sites, and Management sites (right).

Evaluation of CAN Representativeness

Once sites were selected, we checked to see whether states were appropriately represented in the CAN or whether any states were over or under-selected compared to others. To do this we plotted the number and area of selected sites against the number and area of delineated sites (Figures 14-3, 14-4) and fit a linear regression model.

When comparing the number of sites selected with those delineated, North Carolina and New Jersey appeared over-represented while Connecticut and New Hampshire appeared under-represented (Figure 14-3). If this is reexamined by area of sites, Florida and North Carolina appear to be overrepresented and Connecticut, New Hampshire, Pennsylvania, and Massachusetts might be considered under-represented (Figure 14-4).

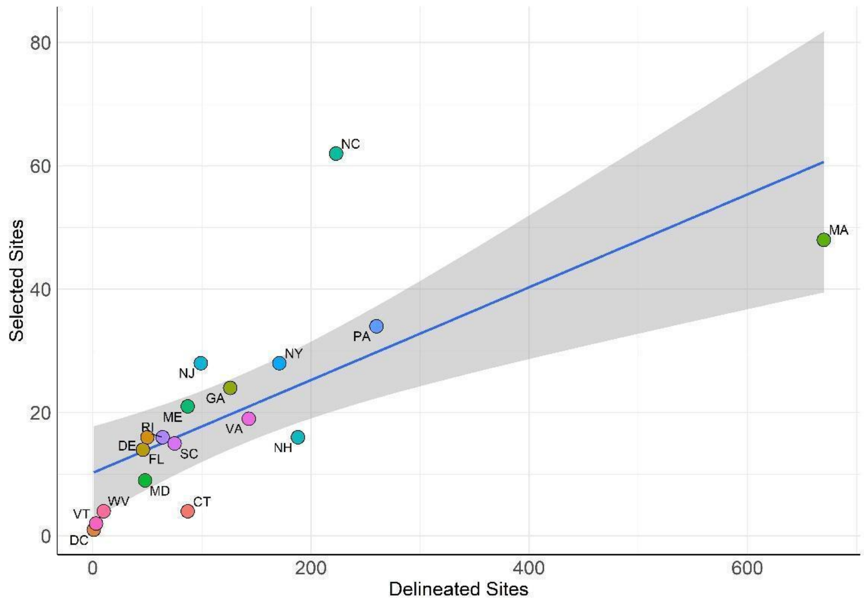


Figure 14-3. Number of sites selected within a state for the Spotted Turtle CAN and the total number of sites delineated within the state. A linear regression is shown in blue, and 95% confidence intervals are depicted in gray.

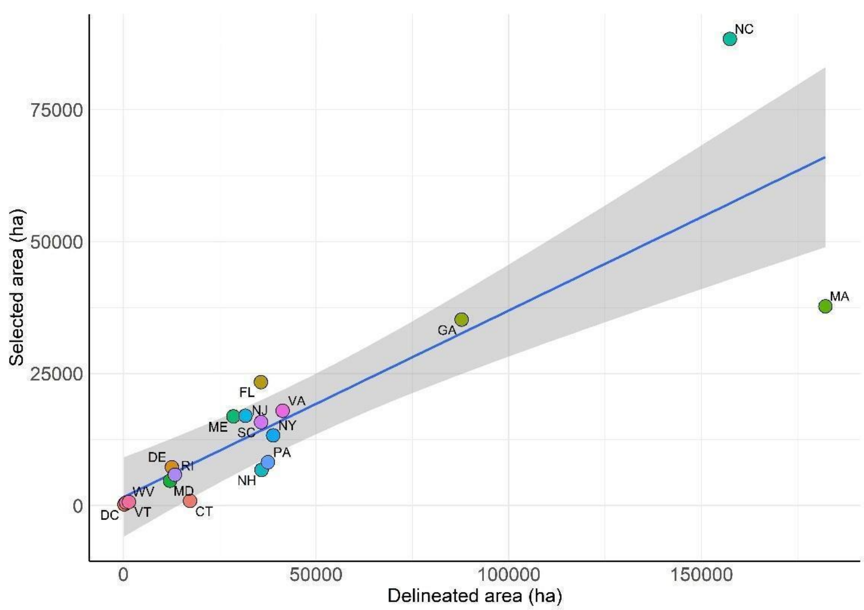


Figure 14-4. Total area (ha) selected within a state for the Spotted Turtle CAN and the total area delineated within Spotted Turtle sites in the state. A linear regression is shown in blue, and 95% confidence intervals are depicted in gray.

However, because Spotted Turtles occur at a large spatial scale within a variety of habitats, the occurrence database we utilized only represents a fraction of actual Spotted Turtle populations and many have yet to be recorded. While this is true throughout the region, this was particularly noted by biologists in Virginia, North Carolina, and South Carolina. Therefore, a regression between selected sites and delineated sites may not be an appropriate measure of representation within a state, especially if that state is relatively under sampled. Therefore, we ran regressions between the sum value of the Spotted Turtle C-SWG habitat model within selected sites and within the state to determine whether a state was over- or under-represented in the CAN based on estimated habitat quality (Figure 14-5).

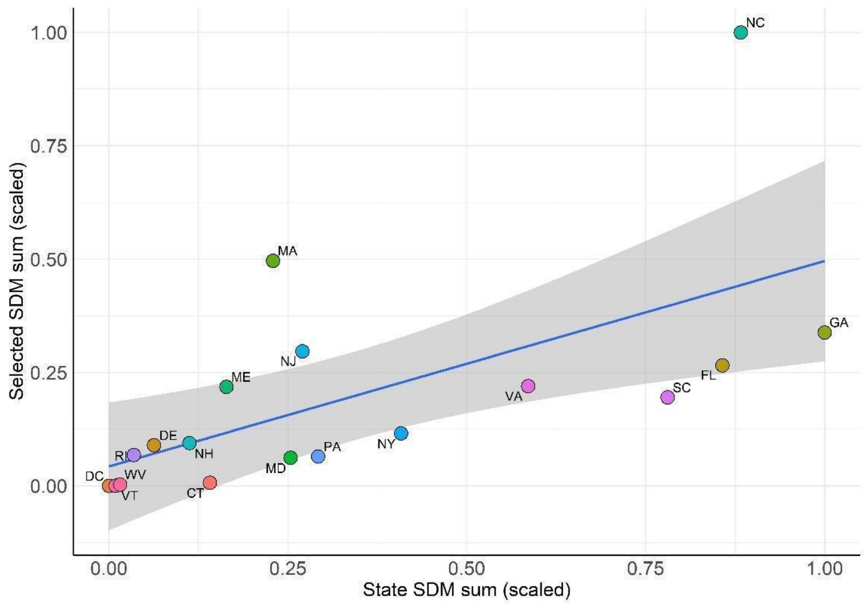


Figure 14-5. The scaled habitat model sum within selected Spotted Turtle sites and the scaled habitat model sum for the state. A linear regression is shown in blue, and 95% confidence intervals are depicted in gray.

The habitat model regression shows that North Carolina, Massachusetts, and New Jersey appear over-represented while Maryland, Pennsylvania, New York, and South Carolina are under-represented (Figure 14-5). While it appears from all regressions that North Carolina is over-represented within the Spotted Turtle CAN (Figures 14-3, 4, 5), it is likely under-represented in terms of record density and likely contains large amounts of currently unmapped habitat. Therefore, additional sampling in the state will likely reveal many additional sites. New York may be under-represented in the CAN because 66% of its sites are based on records from an unknown year and are therefore precluded from the majority of site selection criteria.

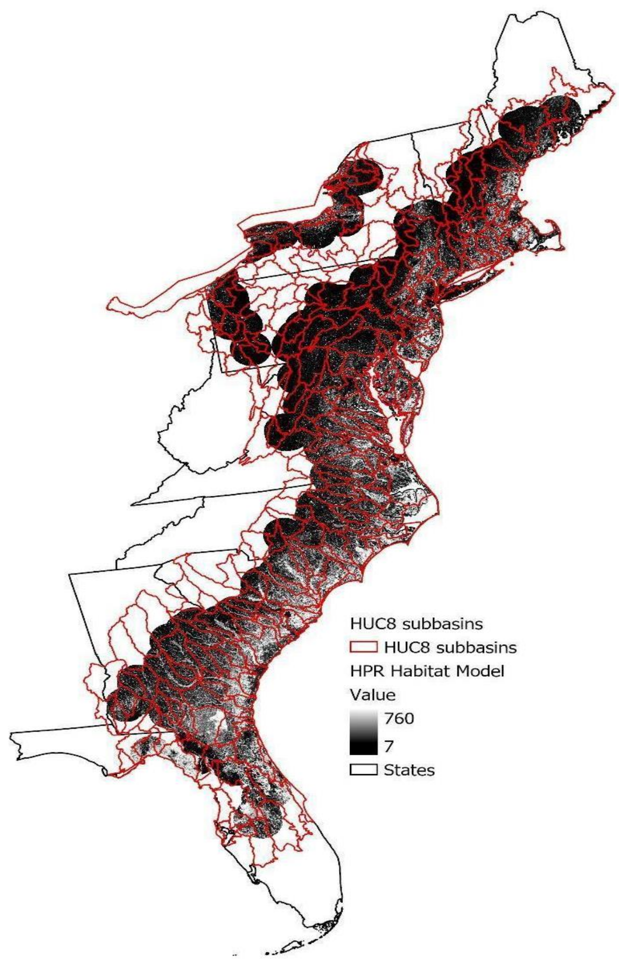
This CAN serves as the starting point for a regional Spotted Turtle conservation and recovery effort. Because there is still much to learn about the distribution of the species, the CAN must necessarily be adaptive and updated at intervals as more information is acquired through additional sampling (see Part VI of this Plan).

Chapter 15. Spotted Turtle Sampling Landscapes

Molly K. Parren and Lisabeth L. Willey

Background

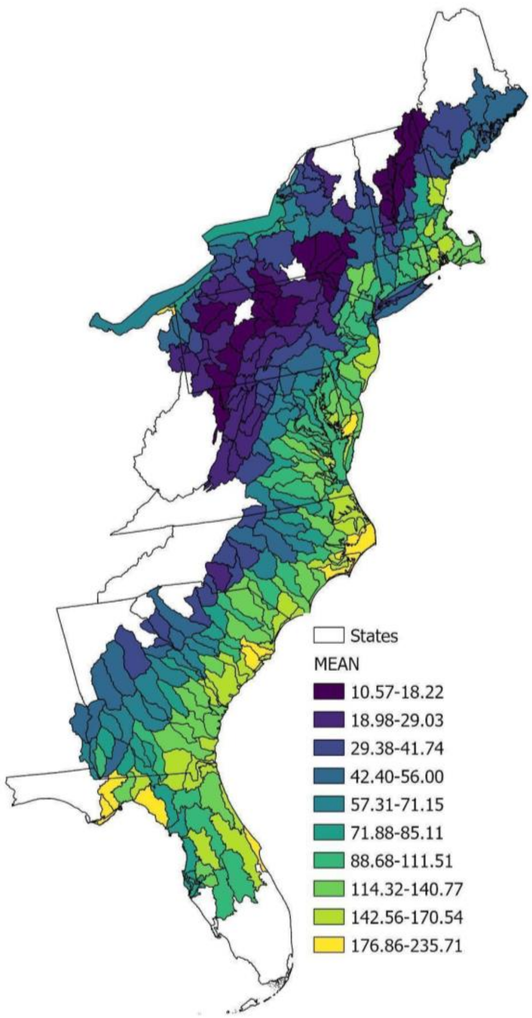
Spotted Turtles occur at a large spatial scale within a variety of habitats and likely go under-reported where they are considered common. Because the site delineation process was record-based, many Spotted Turtle populations were likely excluded due to under-sampling for the species, particularly in certain parts of the species range. Additionally, conversations with regional partners revealed that there are un-delineated areas, particularly in the Southeast, that are known to be good Spotted Turtle habitat where robust populations likely occur. Therefore, we used the Spotted Turtle habitat suitability model developed for this conservation plan to identify HUC8 subbasins that model well but have few Spotted Turtle records and were not extensively surveyed during the 2018–2021 regional population assessment (Map 15-1). These HUCs can serve as sampling priorities going forward in order to evaluate species status in those areas and to identify additional conservation priorities.

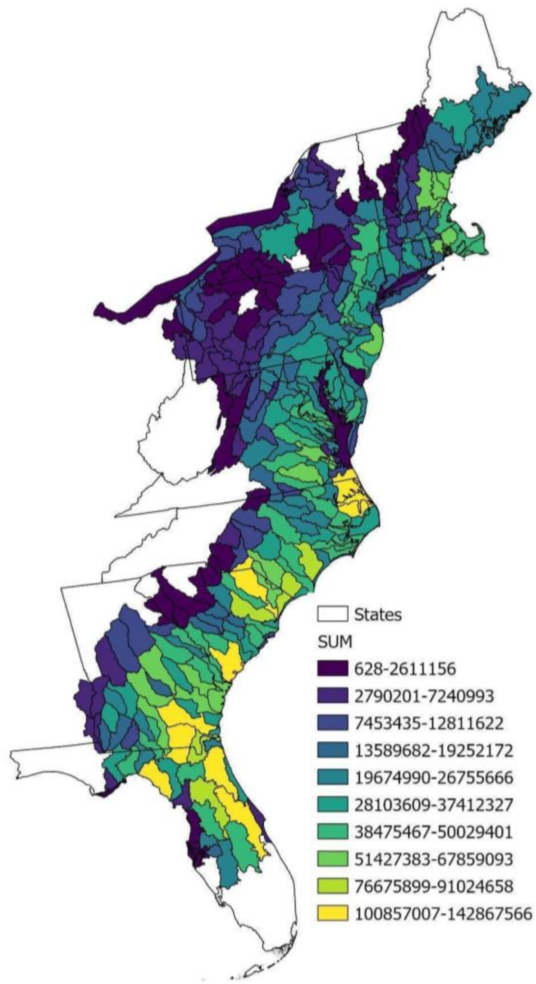


Map 15-1. H.P. Roberts' (HPR) Spotted Turtle habitat model developed for this conservation plan and the HUC8 subbasins that it overlaps.

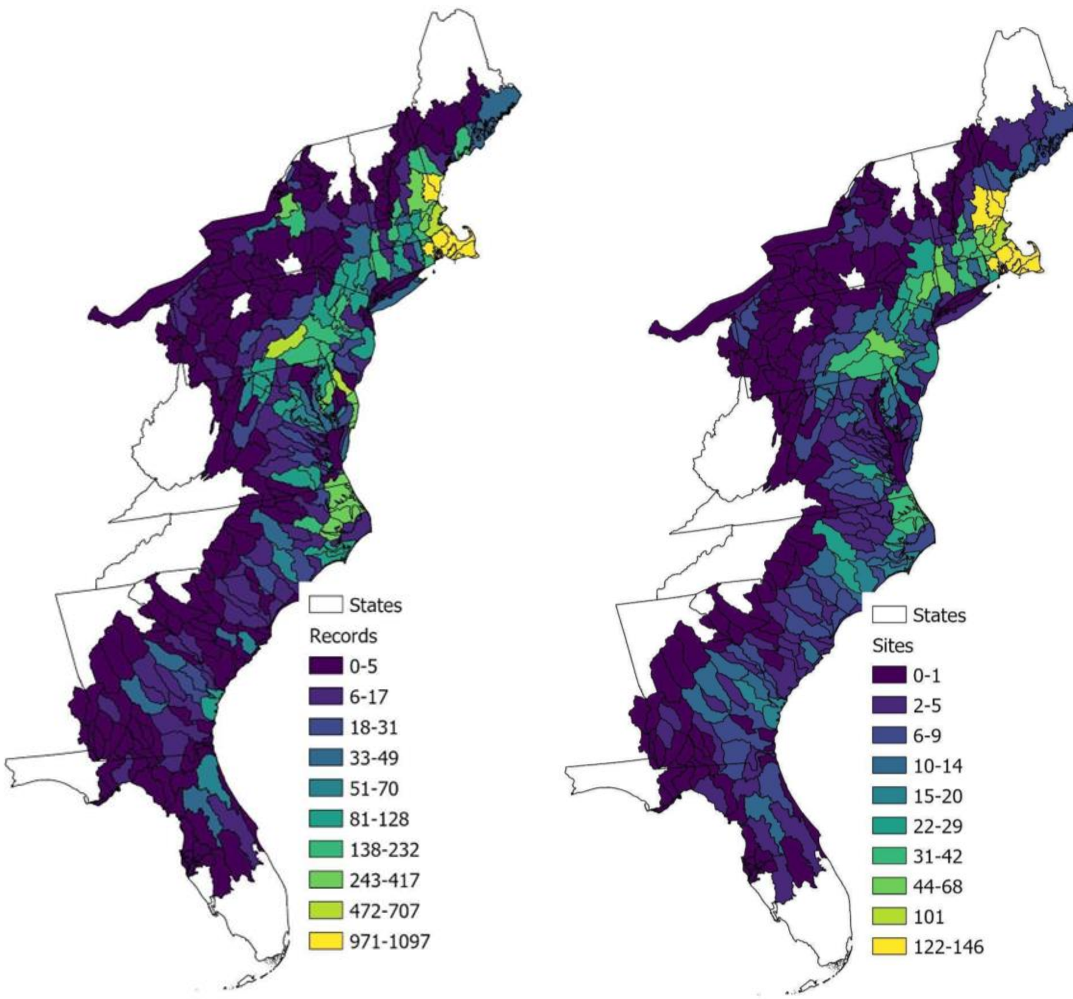
Methods

Relative quality of Spotted Turtle habitat within HUC8 subbasins was calculated in two ways: the mean cell value and the sum of values within the subbasin (Map 15-2) based on the habitat suitability model developed in Chapter 3. Sum was included to account for the overlap of known Spotted Turtle range with the subbasin. In addition to modeled habitat, we also attributed subbasins with the number of delineated Spotted Turtle sites and records they contained (Map 15-3).





Map 15-2. A) Mean habitat model value by HUC8 subbasin (left) and B) sum of habitat model values within a HUC8 subbasin (right).



Map 15-3. A) Number of Spotted Turtle records within a HUC8 subbasin (left) and B) number of delineated Spotted Turtle sites within a HUC8 subbasin (right).

Results

Modeled Spotted Turtle habitat was, on average, higher in subbasins in Florida and Georgia compared to northern regions (Table 15-1; Figures 15-1, 15-2). The number of Spotted Turtle records and associated delineated sites were highest in New England subbasins (Table 15-1; Figures 15-1, 15-2) while C-SWG/RCN sampling effort was highest in southern Mid-Atlantic subbasins (Table 15-1; Figures 15-1, 15-2). Sampling effort was measured in trap checks and sampled area based on 200 m reference plots used in the 2018–2021 regional standardized population assessment (Part III of this Plan).

Table 15-1. Average values for habitat suitability (SDM) and sampling effort for HUC8 subbasins within regions and overall (East Coast). N. Mid-Atlantic: NY, NJ, PA, S. Mid-Atlantic: DE, MD, WV, VA.

Metric	East Coast	New England	N. Mid-Atlantic	S. Mid-Atlantic	Carolinas	Florida/ Georgia
Mean SDM	79.73	70.44	47.52	85.7	100.66	110.17
Sum SDM	22,977,023	17,665,602	12,396,896	17,449,311	35,524,985	37,462,896
# Turtle records	47.26	150.05	33.52	42.95	28.84	8.81
# Delineated sites	8.42	27.12	6.01	4.74	6.22	3.32
% of HUC delineated	1.26	4.7	0.44	0.67	1.1	0.55
% of HUC sampled	0.07	0.1	0.02	0.17	0.02	0.07
# Trap checks	112.82	174.05	56.4	225.54	37.52	100.36

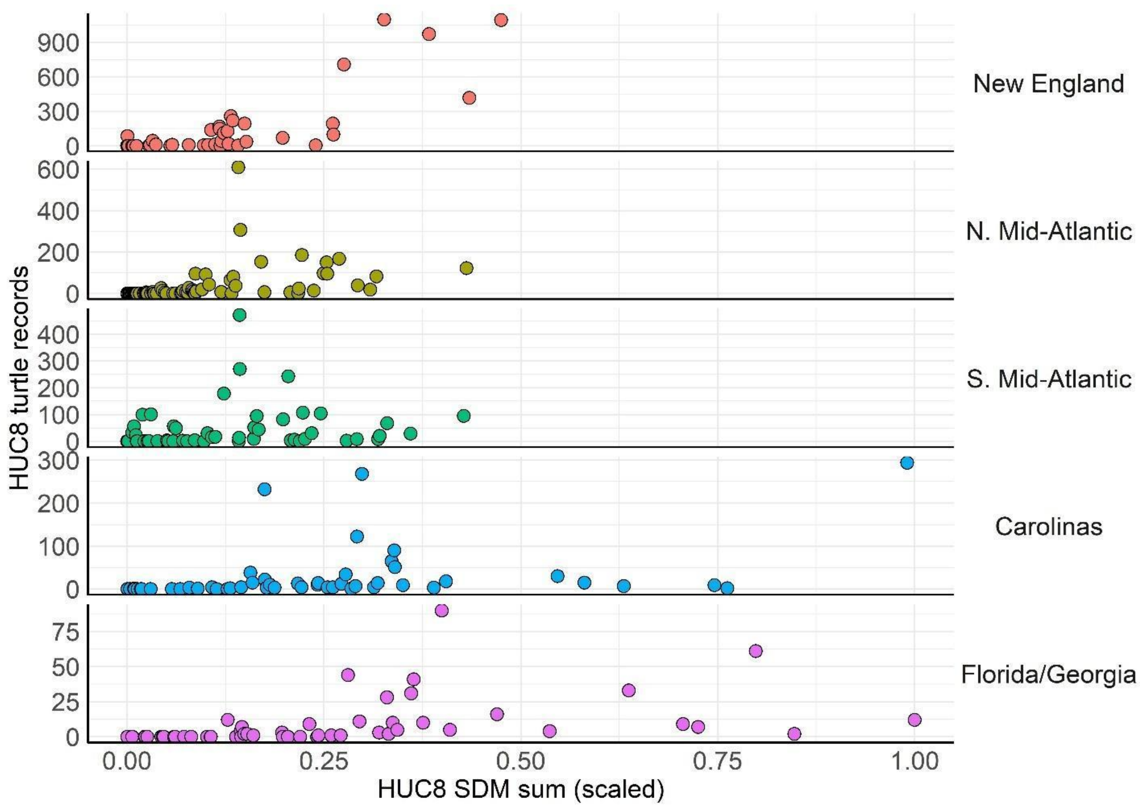


Figure 15-1. Number of Spotted Turtle records within HUC8 subbasins by the sum of SDM values within the HUC, by region. Note: Scale for y axis varies by region.

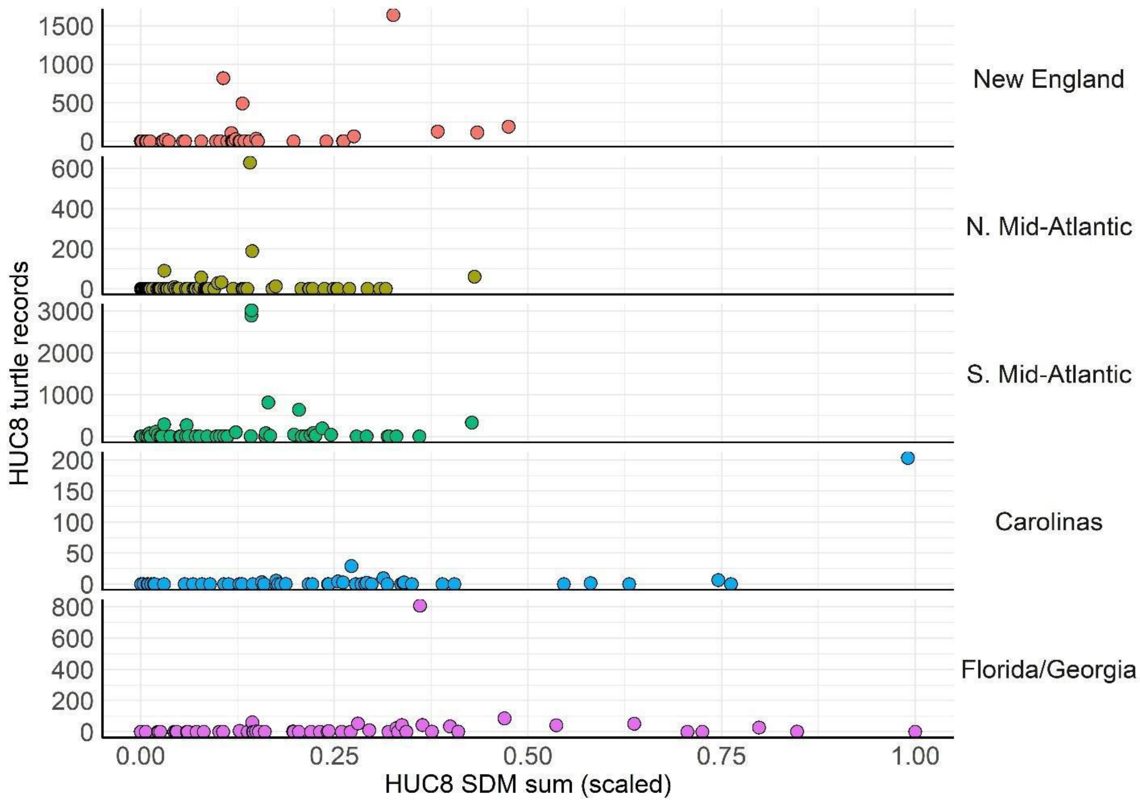


Figure 15-2. Sum of SDM values within HUC8 subbasins by C-SWG sampling effort (number of total trap checks * percent of HUC sampled, based on a 200m radius buffer of traps), by region. Note. Scale for y axis varies by region.

Subbasins were selected as sampling priorities if they had high habitat model sums or means, low numbers of records, low percent area sampled, low number of trap checks, and low percent area within delineated sites. Thresholds utilized in selection are presented in Table 15-2.

Table 15-2. Metrics considered for HUC8 subbasin selection and their 25th, 50th, 75th, and 95th percentiles. Cells highlighted in gray were used as thresholds for selection.

Metric	25th percentile	50th percentile	75th percentile	95th percentile
Mean SDM	36.49	71.88	116.1	166.9
SDM Sum	4,230,793	16,747,662	34,349,117	66,604,740
Records	0	4.00	30	217.3
Sampled Percent	0	0	0.03	0.45
Trap Checks	0	0	80	598.7
Delineated site percent	0	0.26	1.06	4.52

Final selection

Using the criteria outlined above, 26 HUC8 subbasins within six states were initially selected as sampling priorities. We shared these selections with state partners to make adjustments using their expert opinion. Following this process, half of the original selections were removed and replaced with 15 new selections resulting in 28 subbasins identified as sampling priorities within the five southeastern states (Map 15-4). Four subbasins were selected in Virginia, five were selected in both Georgia and Florida, and seven were selected in both North and South Carolina.

While all subbasins in the Coastal Plain of North Carolina were suggested as possible selections, we subset the selection to include subbasins with higher habitat model scores and fewer Spotted Turtle records. This was done to identify sampling opportunities that will fill information gaps and are most likely to yield Spotted Turtle captures. Once these subbasins have been sampled, we then suggest sampling the remaining Coastal Plain subbasins of North Carolina.

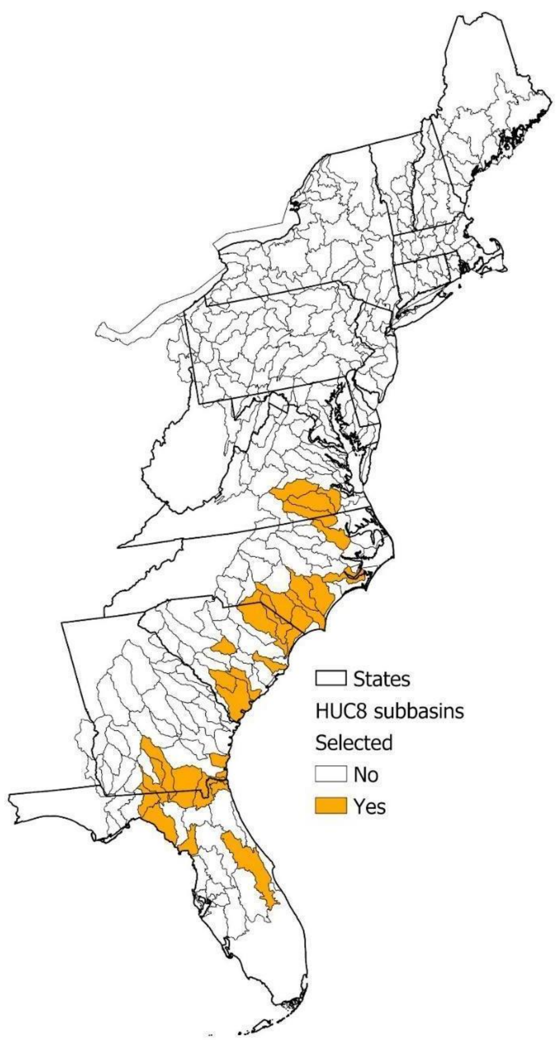


Figure 15-4. HUC 8 subbasins identified as priorities for sampling based on high modeled habitat score but limited Spotted Turtle records and C-SWG/RCN sampling, and expert opinion.

Part VI. Conservation Action Plan

Chapter 16. Conservation Action Plan

Our fundamental goal in the development of this regional Conservation Plan is to support the evolutionary potential of the Spotted Turtle in the eastern United States by conserving representative and **self-sustaining populations throughout the extent of the current occupied range.** We define the "current occupied range" as the area known or expected to be occupied by Spotted Turtles during the period from 1990–2022, recognizing that many populations were lost prior to 1990 due to habitat loss and other factors. We selected this timeframe because the full geographic distribution of populations prior to 1990 is largely unknown. Our view of the current Spotted Turtle distribution is likely influenced to some extent by the "shifting baseline" syndrome (Soga and Gaston 2018), but this spatially explicit plan serves as a potential hedge against further declines in range extent and population abundance. In furtherance of the fundamental goal, we aim to: 1) maintain a spatially-explicit and dynamic database of **resilient** "Focal Core Areas" that is **representative** of the ecological, genetic, and political context in which the species currently lives, and has sufficient **redundancy** to maintain the capacity for Spotted Turtles to evolve in the face of severe environmental change; 2) reduce other major threats and undertake restoration and management in areas identified as "Management Opportunities"; 3) maintain adaptive capacity of Spotted Turtles by ensuring range-wide representation and habitat integrity of Focal Core Areas; 4) address data gaps including additional sampling at those sites designated as "Sampling Opportunities" and "Sampling Landscapes", and 5) continue multi-jurisdictional collaboration, adapting and updating this Plan as new information becomes available.

To prioritize actions necessary to meet the fundamental goal, working group partners engaged in conversations during regular monthly meetings and participated in an expert elicitation process by poll. Seventeen partners from throughout the eastern United States participated in the process. Overall, land protection and curtailing illegal collection were ranked as the most important actions needed to maintain viable populations of Spotted Turtles region wide. Results from the poll (Fig 16-1 and 16-2) were used to identify the following necessary objectives and actions, which were then reviewed by all partners prior to finalization.

Objective 1. Minimize net degradation/loss of site quality within "Focal Core Areas" identified in the Conservation Area Network (CAN).

An important benchmark for Spotted Turtle conservation is the maintenance of robust and viable populations within Focal Core Areas (which encompass 8% of all delineated Spotted Turtle sites and 25% of delineated habitat). However, population viability is contingent upon numerous complex landscape and population processes, including connectivity to other populations, and the demographic parameters necessary to assess trends or viability can be highly variable over decadal time scales. Further, estimating the size and demographic parameters necessary to demonstrate viability of all the representative Focal Core Areas would require an impractical investment of sampling effort and funding, and even with robust population-specific data, standard PVA metrics can be imprecise. For this reason, we propose the development and use of composite metrics that will be tracked over time to serve as proxies for population viability at Focal Core Areas. The metrics are a way to measure overall "site quality" and will come from 3 sources: 1) site-specific population demographic information (e.g., population size, population structure, evidence of recruitment), where available, 2) remotely sensed landcover information (e.g., the National Landcover Database), and 3) site-specific habitat resource information (e.g., availability of nesting habitat). While site-specific population information is ideal and should be the primary means of evaluation, data availability varies across the region, necessitating the use of all three approaches. Each of the three composite metrics will be tracked individually with the goal of no net decline in site quality across the region. To this end, we propose the following actions:

1. Develop and maintain a **site-level tracking table** (similar to that used for Wood Turtles in the Northeast) to record the status of Focal Core Areas including known population size, age structure, presence and quality of nesting habitat, amount and quality of wetland habitat, landscape fragmentation, connectivity, and number of acres conserved. Proposed, site-specific management actions necessary to increase site quality would also be spatially tracked, including:
    a. Road mortality mitigation
    b. Agricultural mitigation
    c. Habitat restoration
    d. Nesting habitat management
    e. Wetland and hydrologic restoration and management
    f. Improved population connectivity
    g. Monitoring sites for poaching activity

2. Avoid and **minimize additional habitat loss** in Focal Core Areas through focused land conservation efforts. In particular, conservation of wetland and adjacent, connecting upland habitat (generally a forest matrix) should be prioritized to minimize wetland fragmentation and the separation of wetland and nesting habitat.

3. State agencies should **update environmental review policies and procedures** to develop applicable recommendations under state Endangered Species Acts or other regulatory mechanisms. Spotted Turtles have state legal listing status (endangered, threatened, special concern) throughout a substantial portion of their eastern range and are subject to protections from take, kill, injury, harassment, and/or significant habitat disturbance in some states. Where regulatory mechanisms exist, environmental review should emphasize the configuration and connectivity of remaining habitats while minimizing the overall project footprint. For example, the difference between a well-designed subdivision (e.g., low density

and clustered lots with strategically deeded open space component providing well-buffered and connected wetlands) informed by consultation with the state agency of jurisdiction and a poorly executed, sprawling development can mean the difference between local population persistence and extirpation. Notably, there are some eastern states with strong at-risk species regulatory review programs (e.g., Massachusetts and Maine) that might be consulted as potential models for exemplary development review protocols.

4. Develop a **technical assistance packet** that state biologists can use to communicate with managers, land trusts, and landowners to increase land protection and beneficial management in high priority sites.

5. Continue **sampling at Focal Core Areas** to complete a baseline population assessment at each, and track changes in population size, demographic parameters, and effectiveness of management over time, where possible. Sampling emphasis should be placed on those sites thought to be the best populations and the most vulnerable in order to track change at these important sites over time.

6. Undertake **management and restoration actions** identified at each Focal Core Area to increase site quality. Management actions should consider other Species of Greatest Conservation Need (SGCN) that occur at the site and whether the action would also improve habitat for priority at-risk species.

7. Assess the need for **regulatory changes or species status changes** in order to more effectively protect Focal Core Areas. As noted in Chapter 1, not all conservation organizations agree on the global listing status of this species. The International Union for the Conservation of Nature (IUCN)'s Tortoise and Freshwater Turtle Specialist Group (TFTSG) classify Spotted Turtles as Endangered (van Dijk 2010). By contrast, NatureServe lists the Spotted Turtle G5 ("secure"; NatureServe 2016). Results of sampling and analyses conducted throughout this Plan suggest that although Spotted Turtles are widespread, they have declined substantially and are subject to a suite of on-going threats likely to increase population declines. Therefore, we respectfully recommend G3 or G3G4 (globally vulnerable) as an appropriate status for the species. States should reassess their current legal and state s-ranks (Table 1-3), given currently available information.

8. **Maintain and update** the site action tracking table over time to evaluate change in key metrics.

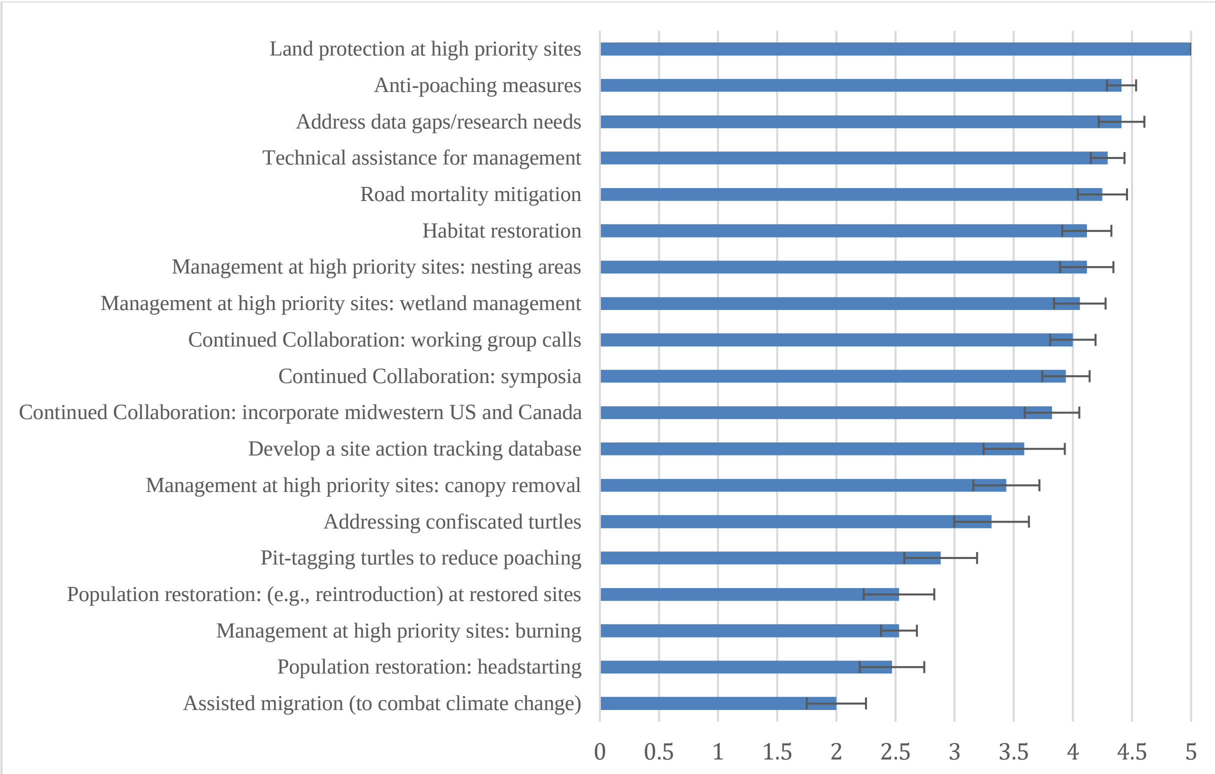


Figure 16-1. Average importance score (0 = least important, 5 = most important) assigned to potential conservation actions from the expert opinion poll.

Objective 2. Reduce major threats besides habitat loss

Habitat loss and related effects (including road mortality) and illegal collection were identified as the major threats to Spotted Turtle populations in Part IV of this Plan. To address habitat loss, partners emphasized the need for land conservation at Focal Core Area sites as part of Objective 1. To complement those efforts, partners identified the following necessary actions to reduce additional threats identified in Part IV.

- ***Collection:*** Apart from land protection, anti-poaching measures were identified as the highest priority action in expert polls. The Collaborative to Combat the Illegal Trade in Turtles (CCITT) has identified, and is undertaking, a number of actions to reduce trade and trafficking of turtles, and the Spotted Turtle working group supports those efforts, including:

    - *Judicial System and Regulations.* Possession and trade rules for Spotted Turtles vary substantially across the region (Table 1-3), making enforcement difficult. The Partners in Amphibian and Reptile Conservation (PARC) have developed model state herpetofauna regulatory guidelines, and the Association of Fish and Wildlife Agencies (AFWA) and the Judiciary and Regulatory Working Group of CCITT are working on updating those guidelines. The objective of these revisions is to provide recommendations to help close existing loopholes and increase law enforcement's ability to implement state regulations. This group is also working to inform prosecutors and judges of the issues related to the illegal collection of turtles, determine if we could get restitution for housing, care, repatriation, and other needs to care for confiscated turtles, and investigate the possibility of protecting sensitive location data for at-risk species.

- *Law Enforcement.* CCITT has also been working to build relationships between biologists and wildlife law enforcement and to increase the awareness about non-game species concerns such that they are a higher priority. The Law Enforcement Working Group of CCITT is involved in training for academy and seasoned officers and the development of standard operating protocols to maintain chain of custody, for biosecurity, and to address prosecution needs. Additionally, this group is working to address internet and cybercrime and encourage citizens to report suspicious behavior. Funding resources are needed to bolster law enforcement's ability to investigate and pursue non-game species cases and for housing of confiscated turtles.

- *Confiscation and Repatriation.* The Confiscation and Repatriation Working Group of CCITT is collaborating with the Association of Zoos and Aquarium and the Turtle Survival Alliance, as well as other partners, to develop a network of facilities able to house confiscated turtles. This effort is part of the AZA's Saving Animals from Extinction (SAFE) program. The CCITT Confiscation and Repatriation group is also developing protocols for use by state biologists and law enforcement officers to guide them through a confiscation case. There are many decisions to make involving health case considerations for the captive turtles, chain of custody of evidence, and timely transfer to a housing facility. The protocols are designed to allow states to begin to prepare for a confiscation before one happens by identifying needed resources and providing helpful decision tools.

- *Human Dimension.* Public outreach is needed to raise awareness about the issue of illegal collection of turtles. Data sharing through citizen scientist databases such as iNaturalist, Herpmapper, and BISON (to name a few) can be a powerful way to obtain large quantities of data quickly for a variety of research projects. For example, this has been very successful to allow a better understanding of species' distribution. Unfortunately, this data can also be used by poachers to identify locations to collect specific species. Most, if not all, of these sites do provide the contributor the ability to obscure or conceal the observation location data from the general public. Data contributors should always consider doing this for Spotted Turtle (as well as other at-risk turtle species) observations. Social media is another place many nature enthusiasts post photos of turtles they find crossing roads or otherwise encounter while in the outdoors. Many modern cameras contain GPS capabilities and embed location information in the image files. Collectors can use the location data to their advantage. Always remove location data from images before posting or, better yet, turn off the GPS capabilities in your camera. Also never provide maps or specific location information for turtle observation in narrative form in your social media posts. The Human Dimensions Working Group of CCITT is also working to gain wider support with stakeholders, identify conservation interventions, develop consistent messaging, and coordinate training of outreach personnel within agencies and conservation organizations.

- *Research.* We need to better understand the quantities of Spotted Turtles being collected and the locations where collection is occurring. The current database system used to track federal confiscation cases (LEMIS) is critically important, and increased attention to tracking of cases is needed to identify patterns in the data and to determine which species are at greatest risk and where. This data will also provide evidence of the need for additional resources to help address the issue and guide how funding and staff time would be best spent. A similar illegal wildlife trade case tracking database is needed at the state level. In the absence of these state-level databases the Data and Research Working Group of CCITT has been gathering information available from public information resources such as news articles and other media accounts. This group is also interested in identifying new methods of forensics that could allow the identification of the geographic origin of confiscated turtles and building capacity for training of wildlife professionals.

- ***Road mortality mitigation measures.*** Road mortality has been identified as a major threat for freshwater turtles, and Spotted Turtles are among the species significantly affected due to their semi-terrestrial habitat use. **Minimizing new road development and "improvements"** (road widening, increased speeds) through and between wetland habitat is most important to maintaining habitat connectivity, and land conservation measures outlined in Objective 1 are key to this effort. In addition, culvert upgrades and improving passage structures, seasonal road closures, strategic use of barrier fencing, reducing speed limits, and use of road signs to alert drivers to turtles in the area have all been proposed, and should be emphasized at both Focal Core Areas and Management Opportunities, though the effectiveness of some of these actions has not been well documented and should be evaluated as part of Objective 4.

- ***Implement management actions at CAN sites.*** Sites identified as Focal Core Areas are the focus of Objective 1. Sites with Management Opportunities (representing 3% of all known Spotted Turtle sites) have also been identified as part of the CAN and undertaking management actions to improve habitat quality at those sites is also a high priority. Many Management Opportunities are already protected, but Spotted Turtles may not currently be a management priority.

- ***Monitor effects of climate change (including sea level rise) on populations.*** Climate change was identified as a potential threat to Spotted Turtle populations (see Appendix 1-A), though the extent of that threat and the specific mechanisms causing population and distribution change are not well understood. Partners suggested monitoring the effects of climate change (including changes in temperature, and precipitation, and sea level) on populations in order to assess the magnitude of the threat and adaptively update this Plan with additional recommended actions as new information becomes available.

Objective 3. Maintain adaptive capacity of known Spotted Turtle populations

To maintain the capacity for the species to evolve under changing environmental conditions, we must ensure that representative populations are conserved across geographies, ecoregions, habitats, and genetic groups. This information has been incorporated into the CAN already, where feasible, by stratifying sites across states, ecoregions, and watersheds, but as new information is obtained, the CAN must be updated to reflect the additional knowledge. We expect that sites will be added as we continue to sample and learn more about the distribution and status of Spotted Turtle populations throughout the region. To that end, we propose the following actions:

- Continue to **sample across the eastern portion of the range** to better understand distribution, with a particular emphasis on "Sampling Opportunities" identified in the CAN (representing 4% of all Spotted Turtle sites) and "Sampling Landscapes".

- **Incorporate genetic information** into the CAN once available by adding genetically unique or diverse sites that are not already included.

- Continue to **collect genetic information** to assess potential evolutionary responses to landscape and climate change.

- **Update the CAN** when information about high priority sites becomes available, adding in new Focal Core Areas when necessary.

Objective 4. Address data gaps

Several important data gaps were identified by partners (Figure 16-1). We propose addressing the following data gaps through continued inter-state collaboration and research:

- **Evaluate the effectiveness of management actions.** Important management actions such as nest site creation and augmentation, canopy removal, increasing connectivity between wetlands via road crossing upgrades, and hydrological improvements are suggested at many sites in order to improve population viability. It is unknown, however, whether many of these actions are effective, and their success is likely context dependent. Therefore, partners identified "evaluating the effectiveness of management actions" as a high priority data gap.

- **Additional surveys.** The need for additional surveys, in the southeastern United States in particular, but also throughout the eastern range, was identified as a high priority data gap. Additional sampling is necessary to identify additional high priority populations, obtain population estimates at additional sites, assess variation across the species range, track changes over time, and to better assess distribution (especially in Sampling Opportunities and Sampling Landscapes: HUC8 subbasins that model well but have few Spotted Turtle records and were not extensively surveyed during the 2018–2021 regional population assessment), all of which were identified as high priority data gaps.

- **Population viability analyses (PVAs)** were also identified as a major data gap; however, regional sampling revealed substantial variation in parameters across the species range, making this type of analysis challenging at large geographic scales. Rather than a broadscale, generalized PVA, individually parameterized PVAs undertaken at finer scales may be more appropriate for this species.

- **Assessing dynamic habitat effects.** As the landscape changes over time, Spotted Turtle populations are likely to be affected in varied, context dependent ways and little is known about how such changes affect the long-term viability and demographics of populations. Therefore, additional studies are warranted related to long-term population dynamics and how they may be influenced by landscape change including hydrology changes, nesting habitat availability and change, subsidized predator dynamics, the effects of canopy cover and ecological succession, and the localized and long-term effects of seawater overwash and nearshore wetland loss.

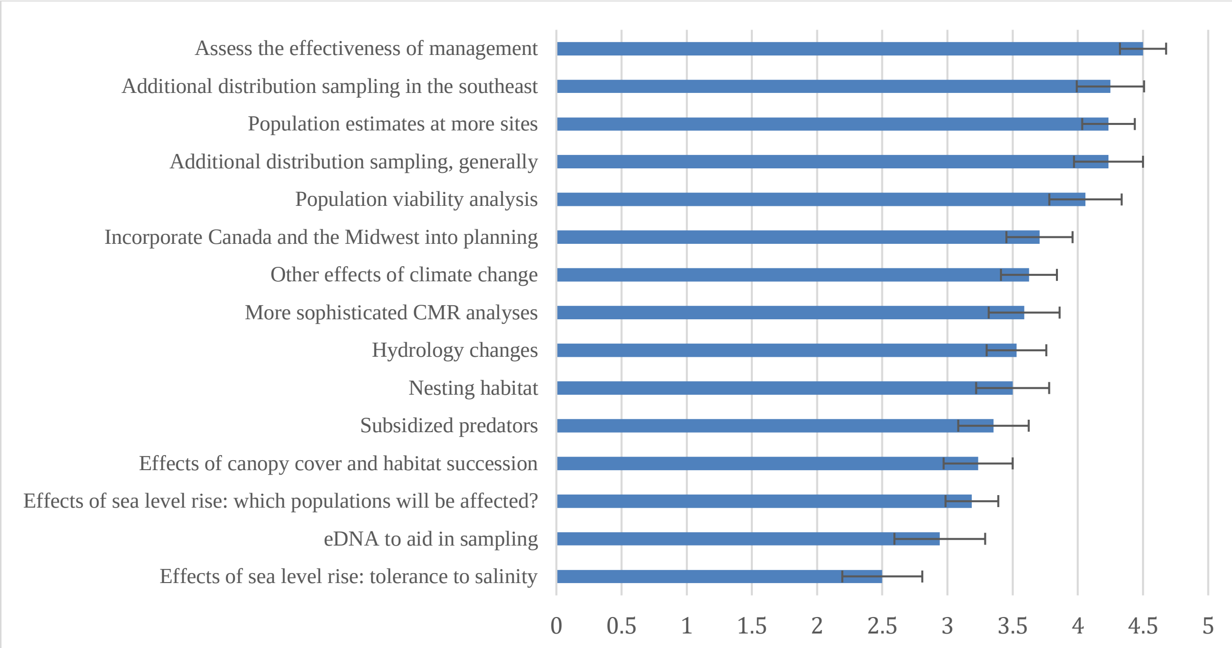


Figure 16-2. Average importance score (0 = least important, 5 = most important) assigned to data gaps and research needs from the expert opinion poll.

Objective 5. Continue Collaboration and Coordination

Continuing to work collaboratively through the Eastern Spotted Turtle Working Group, NEPARC/SEPARC, and NEAFWA/SEAFWA allows partners to better implement and update this Plan, learn from each other, track and quantify change collectively over time, and adapt management strategies as necessary. Lack of resources was identified as a major challenge to implementing conservation actions, and therefore, ways to increase capacity and pursue broad-scale funding opportunities were also identified as important. Specific actions include:

- Prioritize **actions** identified in this Plan and incorporate them into agency and NGO work programs.

- Collaboratively identify and **seek funding opportunities** to undertake high priority conservation actions.

- Hold conservation **symposia** like the one held in West Virginia in 2019 (there is currently a symposium being planned for Pennsylvania during summer 2023).

- Incorporate the **midwestern and Canadian populations** into the broad-scale conservation planning discussion.

- Re-survey sites periodically and collaboratively to assess change. Due to life history characteristics, Spotted Turtle populations are likely to change over relatively long timescales, therefore we suggest that **coordinated population reassessment** should occur on 7–10 year intervals, since change would not likely be measurable at shorter timescales.

- **Update** the Conservation Area Network and Conservation Plan as more information becomes available, especially in conjunction with coordinated resampling events.

- **Continue working group calls** during periods of active coordination, including during population reassessment and Conservation Plan update periods.

Literature Cited

Agha, M., J.R. Ennen, D.S. Bower, A.J. Nowakowski, S.C. Sweat, and B.D. Todd. 2018. Salinity tolerances and use of saline environments by freshwater turtles: implications for sea level rise. Biological Reviews 93(3): 1634–1648.

Allender, M. 2021. Infectious disease in reptiles and its impact on conservation. Meeting presentation for the Collaborative to Combat the Illegal Trade in Turtles. 10 December 2021.

Angoh S.Y.J., J. Freeland, J. Paterson, P.A. Rupasinghe, and C.M. Davy. 2021. Effects of invasive wetland macrophytes on habitat selection and movement by freshwater turtles. Biological Invasions 23: 2271–2288.

Anthonysamy, W.J.B., M.J. Dreslik, M.R. Douglas, D. Thompson, G.M. Klut, A.R. Kuhns, D. Mauger, D. Kirk, G.A. Flowacki, M.E. Douglas, and C.A. Phillips. 2017. Population genetic evaluations within a co-distributed taxonomic group: a multi-species approach to conservation planning. Animal Conservation 21(2): 137–147.

Ashton, K.G., and C.R. Feldman. 2003. Bergmann's rule in nonavian reptiles: turtles follow it, lizards and snakes reverse it. Evolution 57(5): 1151–1163.

Babcock, H.L. 1919. Turtles of the northeastern United States. Peabody Museum of Natural History; Boston.

Baillargeon, S., and L.P. Rivest. 2007. Rcapture: loglinear models for capture-recapture in R. Journal of Statistical Software 19(5): 1–31.

Barrows, C.W. 2011. Sensitivity to climate change for two reptiles at the Mojave–Sonoran Desert interface. Journal of Arid Environments 75: 629–635.

Barton, K. 2016. MuMIn: multi-model inference. R package version 1.15.1. http://CRAN.R-project.org/package1⁄4MuMIn.

Baustian, J.J., and I. A. Mendelssohn. 2015. Hurricane induced sedimentation improves marsh resilience and vegetation vigor under high rates of relative sea level rise. Wetlands 35(4): 795–802.

Beaudry, F., P. deMaynadier., and M.L. Hunter, Jr. 2007. A study of movement, habitat selection, and population viability of Spotted and Blanding's Turtles in southern Maine. A technical report submitted to the U.S. Fish and Wildlife Service and the Maine Department of Inland Fisheries and Wildlife, Augusta, ME.

Beaudry, F., P.G. deMaynadier, and M.L. Hunter, Jr. 2008. Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. Biological Conservation 141: 2550–2563.

Beaudry F., P.G. deMaynadier, and M.L. Hunter, Jr. 2009. Seasonally dynamic habitat use by Spotted (*Clemmys guttata*) and Blanding's Turtles (*Emydoidea blandingii*) in Maine. Journal of Herpetology 43(4): 636–645.

Beaudry, F., P.G. deMaynadier, and M.L. Hunter, Jr. 2010*a*. Nesting movements and the use of anthropogenic nesting sites by Spotted Turtles (*Clemmys guttata*) and Blanding's Turtles (*Emydoidea blandingii*). Herpetological Conservation and Biology 5(1): 1–8.

Beaudry, F., P.G. deMaynadier, and M.L. Hunter, Jr. 2010*b*. Identifying hot moments in road-mortality risk for freshwater turtles. Journal of Wildlife Management 74(1): 152–159.

Berger, J. 1999. Anthropogenic extinction of top carnivores and interspecific animal behaviour: implications of the rapid decoupling of a web involving wolves, bears, moose and ravens. The Royal Society 266(1435): 2261–2267.

Berggren, Å., C. Björkman, H. Bylund, and M.P. Ayres. 2009. The distribution and abundance of animal populations in a climate of uncertainty. Oikos 118(8): 1121–1126.

Bhatia, K.T., G.A. Vecchi, T.R. Knutson, H. Murakami, J. Kossin, K.W. Dixon, and C.E. Whitlock. 2019. Recent increases in tropical cyclone intensification rates. Nature Communications 10(1): 1–9.

Blossey, B., S.B. Endriss, R. Casagrande, P. Häfliger, H. Ainz, A. Dávalos, C. Brown-Lima, L. Tewksbury, and R. S. Bourchier. 2020. When misconceptions impede best practices: evidence supports biological control of invasive *Phragmites*. Biological Invasions 22(3): 873–883.

Bol, L. 2007. Massachusetts forestry conservation management practices for Spotted Turtles. Natural Heritage and Endangered Species Program, Division of Fisheries and Wildlife. 1–21.

Borchers, D.L., and M.G. Efford. 2008. Spatially explicit maximum likelihood methods for capture–recapture studies. Biometrics 64(2): 377–385.

Bougie, T.A., N.W. Byer, C.N. Lapin, M.Z. Peery, J.E. Woodford, and J.N. Paulie. 2020. Wood Turtle (*Glyptemys insculpta*) nest protection reduces depredation and increases success, but annual variation influences its effectiveness. Canadian Journal of Zoology 98(11): 715–724.

Bozek, C.K., S. Prange, and S.D. Gehrt. 2007. The influence of anthropogenic resources on multi-scale habitat selection by raccoons. Urban Ecosystems 10(4): 413–425.

Breisch, A.N. 2006. The natural history and thermal ecology of a population of Spotted Turtles (*Clemmys guttata*) and Wood Turtles (*Glyptemys insculpta*) in West Virginia. Marshall University, Huntington, West Virginia.

Brooks, M.E., K. Kristensen, K.J. van Benthem, A. Magnusson, C.W. Berg, A. Nielse, H.J. Skaug, M. Maechler, and B.M. Bolker. 2017. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. The R Journal 9(2): 378–400.

Brown, J.L., and A.D. Yoder. 2015. Shifting ranges and conservation challenges for lemurs in the face of climate change. Ecology and Evolution 5(6): 1131–1142.

Browne, C.L. and S.J. Hecnar. 2007. Species loss and shifting population structure of freshwater turtles despite habitat protection. Biological Conservation 138: 421–429.

Buchanan, S.W., B. Buffum, and N.E. Karraker. 2017. Response of a Spotted Turtle (*Clemmys guttata*) population to creation of early-successional habitat. Herpetological Conservation and Biology 12(3): 688–700.

Buchanan, S.W., B. Buffum, G. Puggioni, and N.E. Karraker. 2019*a*. Occupancy of freshwater turtles across a gradient of altered landscapes. Journal of Wildlife Management 83(2): 435–445.

Buchanan, S.W., J.J. Kolbe, J.E. Wegener, J.R. Atutubo, and N.E. Karraker. 2019*b*. A comparison of the population genetic structure and diversity between a common (*Chrysemys p. picta*) and an endangered (*Clemmys guttata*) freshwater turtle. Diversity 11(7): 99.

Bull, J.J., R.C. Vogt, and C.J. McCoy. 1982. Sex determining temperatures in turtles: a geographic comparison. Evolution 36(2): 326–332.

Bureau of Transportation Statistics. 2021. North American Rail Lines. United States Department of Transportation, Washington, D.C. <https://data-usdot.opendata.arcgis.com/datasets/usdot::north-american-rail-lines/about>.

Burke, R.L. 2015. Head-starting turtles: learning from experience. Herpetological Conservation and Biology 10(1): 299–308.

Burnham, K.P., and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer, London.

Butler, C.J. 2019. A review of the effects of climate change on chelonians. Diversity 11(8): 138.

Cagle, F.R. 1939. A system of marking turtles for future identification. Copeia 1939(3): 170–173.

Carle, M.V. 2011. Estimating wetland losses and gains in coastal North Carolina: 1994–2001. Wetlands 31(6): 1275–1285.

Carlin, M.L. 2017. Mesopredator release theory: comparing mesocarnivore abundance and prey choices in an urban landscape and impacts on prey populations. International Journal of Environmental Sciences and Natural Resources 2(5):155–161.

Carroll, D.M. 1991. Year of the Turtle. Camden House Publishing, Inc.; Rochester.

Carroll, D.M., and G.R. Ultsch. 2007. Emergence season and survival in the nest of hatchling turtles in southcentral New Hampshire. Northeastern Naturalist 14(2): 307–310.

Cassim, K. 2006. The effectiveness of captive release conservation methods for Spotted Turtles (*Clemmys guttata*). Thesis, Rochester Institute of Technology, Rochester, NY.

Chandler, H.C., B.S. Stegenga, and D.J. Stevenson. 2019. Movement and space use in southern populations of Spotted Turtles (*Clemmys guttata*). Southeastern Naturalist 18(4): 602–618.

Chandler, H.C., B.S. Stegenga, and D.J. Stevenson. 2020. Thermal ecology of Spotted Turtles (*Clemmys guttata*) in two southern populations. Copeia 108(4): 737–745.

Chandler, H.C., B.S. Stegenga, and J.D. Mays. 2022. Compensating for small body size: the reproductive ecology of southern Spotted Turtle (*Clemmys guttata*) populations. Ichthyology & Herpetology 110(2): 268–277.

Chandler, H.C., D.J. Stevenson, J.D. Mays, B.S. Stegenga, W.H. Vaigneur, and M.D. Moore. 2017. A new trap design for catching small Emydid and Kinosternid turtles. Herpetological Review 48(2):323–327.

Chandler, R.B., D.I. King, and C.C. Chandler. 2009. Effects of management regime on the abundance and nest survival of shrubland birds in wildlife openings in northern New England, USA. Forest Ecology and Management 258(7): 1669–1676.

Chandler, R.B., and J.D. Clark. 2014. Spatially explicit integrated population models. Methods in Ecology and Evolution 5(12):1351–1360.

Chaney, N.W., E.F. Wood, A.B. McBratney, J.W. Hempel, T.W. Nauman, C.W. Brungard, and N.P. Odgers. 2016. POLARIS: A 30-meter probabilistic soil series Map of the contiguous United States. Geoderma 274: 54–67.

Chang-Yi, L.I.U., L.U. Ying, S.H.I. Xue-Liad, H.U. Guo-Quan, L.I.U. Qiu-Feng, W.E.I. Chao, and C.A.O. Yun-Fei. 2022. Revisiting BCC-SESM parameters sensitivity with BCC-CSM1.1 CO2-concentration-driven simulations. Advances in Climate Change Research. In press.

Chen, I.C., J.K. Hill, R. Ohlemuller, D.B. Roy, and C.D. Thomas. 2011. Rapid range shifts of species associated with high levels of climate warming. Science 333(6045): 1024–1026.

Church, J.A., and N.J. White. 2011. Sea-level rise from the late 19th to the early 21st century. Surveys in Geophysics 32(4): 585–602.

CITES. 1973. Text of the Convention. Washington, D.C., USA. <https://cites.org/sites/default/files/eng/disc/CITES-Convention-EN.pdf>. Accessed 26 Apr 2022.

CITES. 2000*a*. Amendments to Appendices I and II of CITES: inclusion of *Clemmys guttata* in Appendix II. Eleventh Meeting of the Conference of the Parties, Prop.11.37, Nairobi, Kenya. <https://cites.org/sites/default/files/eng/cop/11/prop/37.pdf>. Accessed 22 April 2022.

CITES. 2000*b*. Consideration of proposals for amendment of Appendices I and II. Doc. 11.59.3, Convention on the International Trade in Endangered Species of Wild Fauna and Flora, Gigiri, Kenya. <https://cites.org/sites/default/files/eng/cop/11/doc/59_03.pdf>. Accessed 25 Apr 2022.

CITES. 2013. Consideration of proposals for amendment of Appendices I and II. Sixteenth meeting of the Conference of the Parties, Prop. 29, Bangkok, Thailand. <https://cites.org/sites/default/files/eng/cop/16/prop/E-CoP16-Prop-29.pdf>. Accessed 22 Apr 2022.

Compton, B. W., W. V. DeLuca, E. B. Plunkett, and K. McGarigal. 2020. Designing sustainable landscapes: Spotted Turtle landscape conservation tools. Report to the US Fish and Wildlife Service, Northeast Atlantic-Appalachian Region.

Connecticut Valley Biological Supply Co. 1962. Biological Materials. Catalogue No. 13. Southampton, Mass.

Connecticut Valley Biological Supply Co. 1964. Biological Materials. Catalogue No. 15. Southampton, Mass.

Cormack, R.M. 1966. A test for equal catchability. Biometrics 22(2): 330–342.

COSEWIC. 2014. COSEWIC assessment and status report on the Spotted Turtle *Clemmys guttata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1–74.

Coulston, J.W., G.G. Moisen, B.T. Wilson, M.V. Finco, W.B. Cohen, and C.K. Brewer. 2012. Modeling percent tree canopy cover: a pilot study. Photogrammetric Engineering & Remote Sensing 78(7): 715–727.

Coulston, J.W., C.E. Blinn, V.A. Thomas, and R.H. Wynne. 2016. Approximating prediction uncertainty for random forest regression models. Photogrammetric Engineering & Remote Sensing 82(3): 189–197.

Dahl, T.E. 1990. Wetland losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 13 pp.

Dahl, T.E. 1999. South Carolina's wetlands–status and trends 1982–1989. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 58 pp.

Dahl, T.E. 2000. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 82 pp.

Dahl, T.E. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 112 pp.

Dahl, T.E. 2011. Status and trends of the wetlands in the conterminous United States 2004 to 2009. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 108 pp.

Dahl, T.E., and C.E. Johnson. 1991. Status and trends of wetlands in the conterminous United States, mid-1970's to mid-1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 28 pp.

Dahl, T.E., and G.J. Allord. 1996. History of wetlands in the conterminous United States. In. J. D. Fretwell, J.S. Williams, and P. J. Redman (compilers) National Water Summary on Wetland Resources. U.S. Geological Survey Water Supply Paper 2425. pp. 19–26.

Davis, C.L., L.N. Rich, Z.J. Farris, M.J. Kelly, M.S. Di Bitetti, Y. Di Blanco, S. Albanesi, M.S. Farhadinia, N. Gholikhani, S. Hamel, et al. 2018. Ecological correlates of the spatial cooccurrence of sympatric mammalian carnivores worldwide. Ecology Letters 21(9): 1401–1412.

Davy, C.M. 2013. Conservation genetics of freshwater turtles. Doctoral dissertation, University of Toronto, Toronto, Canada.

Davy, C.M., and R.W. Murphy. 2014. Conservation genetics of the endangered Spotted Turtle (*Clemmys guttata*) illustrate the risks of "bottleneck tests". Canadian Journal of Zoology 92(2):149–162.

DeCatanzaro, R., and P. Chow-Fraser. 2010. Relationship of road density and marsh condition to turtle assemblage characteristics in the Laurentian Great Lakes. Journal of Great Lakes Research 36(2): 357–365.

DeGraff, J.D., and D.G. Nein. 2010. Predation of Spotted Turtle (*Clemmys guttata*) hatchling by green frog (*Rana clamitans*). Northeastern Naturalist 17(4): 667–670.

Department of Justice Office of Public Affairs. 2020. Chinese man extradited for financing turtle-trafficking ring. United States Department of Justice. <https://www.justice.gov/opa/pr/chinese-man-extradited-financing-turtle-trafficking-ring>. Accessed 27 Apr 2022.

Dewitz, J. 2019. National Land Cover Database (NLCD) 2016 Products: U.S. Geological Survey data release. <https://doi.org/10.5066/P96HHBIE>.

Dismal Swamp Canal Welcome Center (DSCWC). 2017. History of the Dismal Swamp. <https://dismalswampwelcomecenter.com/history/#:~:text=In%20May%201763%2C%20George%20Washington%20made%20his%20first,the%20trees%2C%20and%20use%20the%20land%20for%20farming>. Accessed 18 Dec 2021.

Donnelly, C., M. Larson, and H. Hanson. 2009. A numerical model of coastal overwash. In Proceedings of the Institution of Civil Engineers-Maritime Engineering (Vol. 162, No. 3, pp. 105–114). Thomas Telford Ltd.

Dunson, W.A. 1986. Estuarine populations of the Snapping Turtle (Chelydra) as a model for the evolution of marine adaptations in reptiles. Copeia 1986(3): 741–756.

Edmonds, D., M.J. Dreslik, J.E. Lovich, T.P. Wilson, and C.H. Ernst. 2021. Growing as slow as a turtle: Unexpected maturational differences in a small, long-lived species. PLoS one 16(11): e0259978

Efford, M.G. 2017. secr: Spatially explicit capture-recapture models. R package version 3.1.3. <https://CRAN.R-project.org/package=secr>

Enneson, J.J., and J.D. Litzgus. 2008. Using long-term data and a stage-classified matrix to assess conservation strategies for an endangered turtle (*Clemmys guttata*). Biological Conservation 141(6): 1560–8.

Enneson, J.J., and J.D. Litzgus. 2009. Stochastic and spatially explicit population viability analyses for an endangered freshwater turtle, *Clemmys guttata*. Canadian Journal of Zoology 87(12): 1241–1254.

Ernst, C.H. 1967. A Mating aggregation of the turtle *Clemmys guttata*. Copeia 1967(2): 473–474.

Ernst, C.H. 1970*b*. Home range of the Spotted Turtle, *Clemmys guttata* (Schneider). Copeia 1970(2): 391–39.

Ernst, C.H. 1970*a*. Reproduction in *Clemmys guttata*. Herpetologica 26(2): 228–232.

Ernst, C.H. 1975. Growth of the Spotted Turtle, *Clemmys guttata*. Journal of Herpetology 9(3):313–8.

Ernst, C.H. 1976. Ecology of the Spotted Turtle, *Clemmys guttata* (Reptilia, Testudines, Testudinidae), in southeastern Pennsylvania. Journal of Herpetology 10: 25–33.

Ernst, C.H. 1982. Environmental temperatures and activities in wild Spotted Turtles, *Clemmys guttata*. Journal of Herpetology 16(2): 112–120.

Ernst, C.H., and G.R. Zug. 1994. Observations on the reproductive biology of the Spotted Turtle, *Clemmys guttata*, in southeastern Pennsylvania. Journal of Herpetology 28(1): 99–102.

Ernst, C.H., and J.E. Lovich. 2009. Turtles of the United States and Canada. Second edition. John Hopkins University Press, Baltimore, Maryland, USA.

Ernst, C.H., J.E. Lovich and R.W. Barbour. 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington, D.C.

Ernst, C.H., M.F. Hershey, and R.W Barbour. 1974. A new coding system for marking hard-shelled turtles. Transactions of the Kentucky Academy of Science. 35: 27–38

Eskew, E.A., A.M. White, N. Ross, K.M. Smith, K.F. Smith, J.P. Rodríguez, C. Zambrana-Torrelio, W.B. Karesh, and P. Daszak. 2020. United States wildlife and wildlife product imports from 2000–2014. Scientific Data 7(1): 1–8.

Ewert, M.A., C.R. Etchberger, and C.E. Nelson. 2004. Turtle sex-determining modes and TSD patterns, and some TSD pattern correlates, pp. 21–32. In N. Valenzuela and V.A. Lance (eds.), Temperature-dependent sex determination in vertebrates. Smithsonian Institution press, Washington, D.C.

Ewert, M.A., J.W. Lang, and C.E. Nelson. 2005. Geographic variation in the pattern of temperature-dependent sex determination in the American Snapping Turtle (*Chelydra serpentina*). Journal of Zoology 265(1): 81–95.

Federal Highway Administration. 2013. Highway Functional Classification Concepts, Criteria and Procedures. U.S. Department of Transportation.

Federal Highway Administration. 2018*a*. Highway Performance Monitoring System (HPMS). Department of Transportation, Washington, D.C. <https://www.fhwa.dot.gov/policyinformation/hpms/shapefiles.cfm>.

Federal Highway Administration. 2018*b*. National Bridge Inventory. Department of Transportation, Washington, D.C. <https://www.fhwa.dot.gov/bridge/nbi/ascii2019.cfm>.

Feng, C.Y., D. Mauger, J.P. Ross, and M.J. Dreslik. 2019*a*. Size and structure of two populations of Spotted Turtle (*Clemmys guttata*) at its western range limit. Herpetological Conservation and Biology 14(3): 648–658.

Feng, C.Y., J.P. Ross, D. Mauger, and M.J. Dreslik. 2019*b*. A long-term demographic analysis of Spotted Turtles (*Clemmys guttata*) in Illinois using matrix models. Diversity 11(226): 1–23.

Fick, S.E., and R.J. Hijmans, 2017. WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37(12): 4302–4315.

Fiske, I.J., and R.B. Chandler. 2011. Unmarked: an R package for fitting hierarchical models of wildlife occurrence and abundance. Journal of Statistical Software 43: 1–23.

Foulis, D.B., and R.W. Tiner. 1994*a*. Wetland status and trends in St. Marys County, Maryland (1981–82 to 1988–89). U.S. Fish and Wildlife Service, Hadley, MA. Ecological Services report to Maryland Dept. of Natural Resources. 14 pp.

Foulis, D.B., and R.W. Tiner. 1994*b*. Wetland trends for selected areas of the Casco Bay estuary of the Gulf of Maine (1974–77 to 1984–87). U.S. Fish and Wildlife Service, Hadley, MA. Ecological Services report R5-94/1, 15 pp.

Foulis, D.B., and R.W. Tiner. 1994*c*. Wetland trends for selected areas of the coast of Massachusetts, from Plum Island to Scituate (1977 to 1985–86). U.S. Fish and Wildlife Service, Hadley, MA. Ecological Services report to U.S. Fish and Wildlife Service, Gulf of Maine Project. 16 pp.

Foulis, D.B., J.A. Eaton, and R.W. Tiner. 1994*d*. Wetland trends for selected areas of the Gulf of Maine, from York, Maine to Rowley, Massachusetts (1977 to 1985–86). U.S. Fish and Wildlife Service, Hadley, MA. Ecological Services report to U.S. Fish and Wildlife Service, Gulf of Maine Project. 15 pp.

Frayer, W.E., T.J. Monahan, D.C. Bowden, and F.A. Graybill. 1983. Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950's to 1970's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 36 pp.

Freedberg, S., C. Lee, and M. Pappas. 2011. Agricultural practices alter sex ratios in a reptile with environmental sex determination. Biological Conservation 144: 1159–1166.

Garrison, J.C., H.G. Small, and N.H. Nazdrowicz. 2021. *Clemmys guttata* (Spotted Turtle). Nesting. Herpetological Review 52(4): 842–843.

GBIF.org (25 August 2020) GBIF Occurrence Download https://doi.org/10.15468/dl.twgxw8

Geller, G.A., and S.L. Parker. 2022. What are the primary cues used by mammalian predators to locate freshwater turtle nests? A critical review of the evidence. Frontiers in Ecology and Evolution 2022(9).

Gibbons, J.W. 1989. Why do turtles live so long? BioScience 37(4): 262–269.

Gibbons, J.W., D.E. Scott, T.J. Ryan, K.A. Buhlmann, T.D. Tuberville, B.S. Metts, J.L. Greene, T. Mills, Y. Leiden, S. Poppy, and C.T. Winne. 2000. The Global Decline of Reptiles, Déjà Vu Amphibians: Reptile species are declining on a global scale. Six significant threats to reptile populations are habitat loss and degradation, introduced invasive species, environmental pollution, disease, unsustainable use, and global climate change. BioScience 50(8): 653–666.

Gibbs, J.P., and D.A. Steen. 2005. Trends in sex ratios of turtles in the United States: implications of road mortality. Conservation Biology 19(2): 552–556.

Gilchrist, G.W. 1995. Specialists and generalists in changing environments. I. Fitness landscapes of thermal sensitivity. The American Naturalist 146(2): 252–270.

Glades Herp, Inc. 1998–2013. Various price lists for turtles accessed via the Wayback Machine (archive.org) for gherp.com. Fort Myers and Bushnell, FL.

Government of Canada. 2017. Species at Risk Act operational policy and procedures. Guidelines on characterizing recovery and developing population and distribution objectives. Working Draft December 2017.

Graham, T.E. 1995. Habitat use and population parameters of the Spotted Turtle, *Clemmys guttata*, a species of special concern in Massachusetts. Chelonian Conservation and Biology 1(3): 207–214.

Grenouillet, G., L. Buisson, N. Casajus, and S. Lek. 2011. Ensemble modelling of species distribution: the effects of geographical and environmental ranges. Ecography 34(1): 9–17.

Guiden, P.W., S.L. Bartel, N.W. Byer, A.A. Shipley, and J.L. Orrock. 2019. Predator–prey interactions in the Anthropocene: reconciling multiple aspects of novelty. Trends in Ecology & Evolution 34(7): 616–627.

Hallfors, M.H., J. Liao, J. Dzurisin, R. Grundel, M. Hyvärinen, K. Towle, G.C. Wu, and J.J. Hellmann. 2016. Addressing potential local adaptation in species distribution models: implications for conservation under climate change. Ecological Applications 26(4): 1154–1169.

Hammerson, G., B. Van Dam, and J. D. Soule. 2010. NatureServe Explorer: Spotted Turtle (*Clemmys guttata*).<https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.100580/Clemmys_guttata>. Accessed 1 Mar 2020.

Hanley, J.A., and B.J. McNeil. 1982. The meaning and use of the area under a receiver operating characteristics curve. Radiology 143(1): 29–36.

Hansen, M.C., P.V. Potapov, R. Moore, M. Hancher, S.A. Turubanova, A. Tyukavina, D. Thau, S.V. Stehman, S.J. Goetz, T.R. Loveland, and A. Kommareddy. 2013. High-resolution global maps of 21st-century forest cover change. Science 342(6160): 850–853.

Harms, H.M. 2008. Conservation of the Spotted Turtle (*Clemmys guttata*): identifying critical demographic and environmental constraints affecting viability. Dissertation, Bowling Green State University, Bowling Green, Ohio.

Hartley, M.J., and M.L. Hunter. 1998. A meta-analysis of forest cover, edge effects, and artificial nest predation rates. Conservation Biology 12(2): 465–469.

Hawkins, N.R., and T.L. Lewis. 2002. Population dynamics of Spotted Turtles (*Clemmys guttata*) at Prairie Road Fen in Clark County, Ohio. Proceedings of the National Conference on Undergraduate Research.

Haxton, T., and M. Berrill. 1999. Habitat selectivity of *Clemmys guttata* in central Ontario. Canadian Journal of Zoology 77(4): 593–599.

Haxton, T., and M. Berrill. 2001. Seasonal activity of Spotted Turtles (*Clemmys guttata*) at the northern limit of their range. Journal of Herpetology 35(4): 606–614.

Haxton, T.J. 1997. Home range and habitat selectivity of Spotted Turtles (*Clemmys guttata*) in Central Ontario: implications for a management strategy. M.Sc. thesis, Trent University, Peterborough, Ontario.

Hays, G.C., A.D. Mazaris, G. Schofield, and J.O. Laloë. 2017. Population viability at extreme sex-ratio skews produced by temperature-dependent sex determination. Proceedings of the Royal Society B: Biological Sciences 284(1848): 20162576.

Heppenheimer, E., D.S. Cosio, K.E. Brzeski, D. Caudill, K.V. Why, M.J. Chamberlain, J.W. Hinton, and B. VonHoldt. 2017. Demographic history influences spatial patterns of genetic diversity in recently expanded coyote (*Canis latrans*) populations. Heredity 120(28): 1–12.

HerpMapper. 2020. HerpMapper- A Global Herp Atlas and Data Hub. <https://www.herpmapper.org>. Accessed 2 Jun 2020.

Hijmans, R.J., and J. van Etten. 2019. raster: Geographic data analysis and modeling. R package version 3.0-7. <http://CRAN.R-project.org/package=raster>

Hijmans, R.J., S. Phillips, J. Leathwick, and J. Elith, J. 2017. Dismo: Species Distribution Modeling. R package version 1.1-4.

Hilgartner, W., D. Merritts, R.C. Walter, M. Rahnis, and C. Bernhardt. 2011. Pre-settlement habitat stability and post-settlement burial of a tussock sedge (*Carex stricta*) wetland in a Maryland Piedmont river valley. Conference paper at the 2011 Bog Turtle Recovery Meeting.

Hody, J.W., and R. Kays. 2018. Mapping the expansion of coyotes (*Canis latrans*) across North and Central America. ZooKeys 759: 81–97.

Howell, H.J., D.T. McKnight, R.A. Seigel. 2016. A novel method of collecting Spotted Turtles (*Clemmy guttata*). Herpetological Review 47(2): 27–31.

Howell, H.J., and R.A. Seigel. 2019. The effects of road mortality on small, isolated turtle populations. Journal of Herpetology 53(1): 39–46.

Howell, H.J., R.H. Legere, Jr., D.S. Holland, and R.A. Seigel. 2019. Long-term turtle declines: protected is a verb, not an outcome. Copeia 107(3): 493–501.

Humphries, J.W. 2002. Distribution of the Spotted Turtle in West Virginia and a study at Altona Marsh. Report to the West Virginia Division of Natural Resources, Non-Game and Natural Heritage Program, Elkins, WV.

Hutchison, V.H., A. Vinegar, and R.J. Kosh, 1966. Critical thermal maxima in turtles. Herpetologica 22(1): 32–41.

Ihlow, F., J. Dambach, J.O. Engler, M. Flecks, T. Hartmann, S. Nekum, H. Rajaei, and D. Rödder. 2012. On the brink of extinction? How climate change may affect global chelonian species richness and distribution. Global Change Biology 18(5): 1520–1530.

Iijima, H. 2020. A review of wildlife abundance estimation models: comparison of models for correct applications. Mammal Study 45(3): 177–188.

IPCC. 2019. Technical Summary [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, E. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.- O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 39–69.

Jackson, H.B., and L. Fahrig. 2015. Are ecologists conducting research at the optimal scale?. Global Ecology and Biogeography 24(1): 52–63.

Janzen, F.J. 1994*a*. Climate change and temperature-dependent sex determination in reptiles. Proceedings of the National Academy of Sciences 91(16): 7487–7490.

Jin, S., C.G. Homer, L. Yang, P. Danielson, J. Dewitz, C. Li, Z. Zhu, G. Xian, and D. Howard. 2019. Overall methodology design for the United States National Land Cover Database 2016 products. Remote Sensing, 11(24): 2971.

Johnson, C.J., D.R. Seip, and M.S. Boyce. 2004. A quantitative approach to conservation planning: using resource selection functions to Map the distribution of mountain caribou at multiple spatial scales. Journal of Applied Ecology 41(2): 238–251.

Johnson, K.A. 1983. The decline of the Spotted Turtle, *Clemmys guttata*, in northeastern Illinois. Bulletin of the Chicago Herpetological Society 18(2): 37–41.

Jones, M.T., H.P. Roberts, and L.L. Willey. 2018. Conservation plan for the Wood Turtle in the northeastern United States. Massachusetts Division of Fisheries & Wildlife and the U.S. Fish & Wildlife Service.

Joyal, L.A., M. McCollough, and M.L. Hunter. 2001. Landscape ecology approaches to wetland species conservation: a case study of two turtle species in southern Maine. Conservation Biology 15(6):1755–1762.

Kaye, D.R.J., K.M. Walsh, and C.M. Ross. 2001. Seasonal movements and habitat preferences for the Spotted Turtle and Eastern Box Turtle in Massachusetts. ICOET 2001 proceedings: A Time for Action. 66–82.

Kirwan, M.L., and J.P. Megonigal. 2013. Tidal wetland stability in the face of human impacts and sea-level rise. Nature 504(7478): 53–60.

Kleopfer, J.D., T.B. Akre, and R. Boettcher. 2014. A guide to the turtles of Virginia. Bureau of Wildlife Resources Special Publication Number 4, Virginia Department of Game & Inland Fisheries. Richmond, VA. 44 pp.

Knight, K. 1985. Spotted Turtle release at United States Geological Survey site. West Virginia Department of Natural Resources Report, Elkins, WV.

Koper, N., and R.J. Brooks. 1998. Population-size estimators and unequal catchability in Painted Turtles. Canadian Journal of Zoology. 76(3): 458–465.

Lancia, R.A., W. Kendall, K.H. Pollock, and J.D. Nichols. 2005. Estimating the number of animals in wildlife populations. In Techniques for Wildlife Investigations and Management; Braun, C.E., Ed.; The Wildlife Society: Bethesda, MD, USA; pp. 106–153.

Lara-Reséndiz, R.A., H. Gadsden, P.C. Rosen, B. Sinervo, and F.R. Méndez-De la Cruz. 2015. Thermoregulation of two sympatric species of horned lizards in the Chihuahuan Desert and their local extinction risk. Journal of Thermal Biology 48: 1–10.

Lawler, J.T., D.D. Ackerly, C.M. Albano, M.G. Anderson, S.Z. Dobrowski, J.L. Gill, N.E. Heller, R.L. Pressey, E.W. Sanderson, and S.B. Weiss. The theory behind, and the challenges of, conserving nature's stage in a time of rapid change. Conservation Biology 29(3): 618-629.

Lewis, T.L., and C.A. Faulhaber. 1999. Home ranges of Spotted Turtles (*Clemmys guttata*) in southwestern Ohio. Chelonian Conservation and Biology 3(3): 430–434.

Lewis, T.L., J.M. Ullmer, and J.L. Mazza. 2004. Threats to Spotted Turtle (*Clemmys guttata*) habitat in Ohio. Ohio Journal of Science 104(3): 65–71.

Litzgus J.D. 2006. Sex differences in longevity in the Spotted Turtle (*Clemmys guttata*). Copeia 2006(2): 281–288.

Litzgus, J.D., and R.J. Brooks. 1998*b*. Growth in a cold environment: body size and sexual maturity in a northern population of Spotted Turtles, *Clemmys guttata*. Canadian Journal of Zoology 76(5):773–782.

Litzgus, J.D., and R.J Brooks. 1998*a*. Reproduction in a northern population of *Clemmys guttata*. Journal of Herpetology 32(2): 252–259.

Litzgus, J.D., and R.J. Brooks. 2000. Habitat and temperature selection of *Clemmys guttata* in a northern population. Journal of Herpetology 34(2): 178–185.

Litzgus, J.D., and T.A. Mousseau. 2003. Multiple clutching in southern Spotted Turtles, *Clemmys guttata*. Journal of Herpetology 37(1): 13–23.

Litzgus, J.D., and T.A. Mousseau. 2004*a*. Demography of a southern population of the Spotted Turtle (*Clemmys guttata*). Southeastern Naturalist 3(3): 391–400.

Litzgus, J.D., and T.A. Mousseau. 2004*b*. Home range and seasonal activity of southern Spotted Turtles (*Clemmys guttata*): implications for management. Copeia 2004(4): 804–817.

Litzgus, J.D., and T.A. Mousseau. 2006. Geographic variation in reproduction in a freshwater turtle (*Clemmys guttata*). Herpetologica 62(2): 132–140.

Litzgus, J.D., F. Bolton, and A.I. Schulte-Hostedde. 2008. Reproductive output depends on body condition in Spotted Turtles (*Clemmys guttata*). Copeia 2008(1): 86–92.

Litzgus, J.D., J.P. Costanzo, R.J. Brooks, and R.E. Lee Jr. 1999. Phenology and ecology of hibernation in Spotted Turtles (*Clemmys guttata*) near the northern limit of their range. Canadian Journal of Zoology 77(9): 1348–1357.

Litzgus, J.D., and R.J. Brooks. 1998*c*. Testing the validity of counts of plastral scute rings in Spotted Turtles, *Clemmys guttata*. Copeia 1998(1): 222–225.

Litzgus, J.D., S.E. DuRant, and T.A. Mousseau. 2004. Clinal variation in body and cell size in a widely distributed vertebrate ectotherm. Oecologia 140(4): 551–558.

Litvaitis, J.A., R. Villafuerte, F. Palomares, M. Delibes, and P. Ferreras. 1996. Intraguild predation, mesopredator release, and prey stability. Conservation Biology 10(2): 676–679.

Loarie, S.R., P.B. Duffy, H. Hamilton, G.P. Asner, C.B. Field, and D.D. Ackerly. 2009. The velocity of climate change. Nature 462(7276): 1052– 1055.

Lovich, J.E. 1988. Geographic variation in the seasonal activity cycle of Spotted Turtles, *Clemmys guttata*. Journal of Herpetology 22(4): 482–485.

Lovich, J.E. 1989. The Spotted Turtles of Cedar Bog: historical analysis of a declining population. Proceedings of the Cedar Bog Symposium II. Ohio Historical Society, Columbus, Ohio. pp 23–28.

Mali, I., D. Haynes, and M.R.J. Forstner. 2014. Effects of bait type, bait age, and trap hours on capture success of freshwater turtles. Southeastern Naturalist 13(3): 619–625.

Mali, I., D.J. Brown, M.C. Jones, and M.R.J. Forstner. 2012. Switching bait as a method to improve freshwater turtle capture and recapture success with hoop net traps. Southeastern Naturalist 11(2): 311–318.

Marchand, M.N., and J.A. Litvaitis. 2004. Effects of landscape composition, habitat features, and nest distribution on predation rates of simulated turtle nests. Biological Conservation 117(3): 243–251.

Markle, C.E., N.A. Sandler, H.C.A. Freeman, and J.M. Waddington. 2021. Multi-scale assessment of rock barrens turtle nesting habitat: effects of moisture and temperature on hatch success. Icthyology and Herpetology 109(2): 507–521.

Marmion, M., M. Parviainen, M. Luoto, R.K. Heikkinen, and W. Thuiller. 2009. Evaluation of consensus methods in predictive species distribution modelling. Diversity and Distributions 15(1): 59–69.

Matter, W.J., and R.W. Mannan. 2005. How do prey persist?. The Journal of Wildlife Management. 69(4): 1315–1320.

McCoy, E.D., R.D. Moore, H.R. Mushinsky, and S.C. Popa. 2011. Effects of rainfall and the potential influence of climate change on two congeneric tortoise species. Chelonian Conservation and Biology 10(1): 34–41.

McGarigal, K., H.Y. Wan, K.A. Zeller, B.C. Timm, and S.A. Cushman. 2016. Multiscale habitat modeling: a review and outlook. Landscape Ecology 31(6): 1161–1175.

McGarigal, K., S. A. Cushman, and E. Ene. 2012. FRAGSTATS v4: spatial pattern analysis program for categorical and continuous maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. <http://www.umass.edu/landeco/research/fragstats/fragstats.html.> Accessed 11 Nov 2014.

Mcknight, D.T., and D.B. Ligon. 2017. Correcting for unequal catchability in sex ratio and population size estimates. PLoS one 12(8): e0184101.

McLachlan, J.S., J.J. Hellmann, and M.W. Schwartz. 2007. A framework for debate of assisted migration in an era of climate change. Conservation Biology 21(2): 297–302.

Mendelssohn, I.A., and N.L. Kuhn. 2003. Sediment subsidy: effects on soil–plant responses in a rapidly submerging coastal salt marsh. Ecological Engineering 21(2-3): 115–128.

Merow, C., M.J. Smith, T.C. Edwards Jr., A. Guisan, S.M. McMahon, S. Normand, W. Thuiller, R.O. Wüest, N.E. Zimmermann, and J. Elith. 2014. What do we gain from simplicity versus complexity in species distribution models?. Ecography 37(12): 1267–1281.

Metzler, K.J., and R.W. Tiner. 1992. Wetlands of Connecticut. State Geological and Natural History Survey of Connecticut report. Department of Environmental Protection and U.S. Fish and Wildlife Service. 130 pp.

Meylan, P.A. 2006. *Clemmys guttata* – Spotted Turtle. In Meyland, P.A. (Ed.) 2006. Biology and Conservation of Florida Turtles. Chelonian Research Monographs 3: 226–234.

Milam, J.C. 1997. Home range, habitat use, and conservation of Spotted Turtles (*Clemmys guttata*) in central Massachusetts. M.Sc. Thesis, University of Massachusetts, Amherst, MA.

Milam, J.C., and S.M. Melvin. 2001. Density, habitat use, movements, and conservation of Spotted Turtles (*Clemmys guttata*) in Massachusetts. Journal of Herpetology 35: 418–427.

Mitchell, J.C. 1994. The reptiles of Virginia. Smithsonian Institution Press, Washington, D.C. 352 pp.

Mitchell, J.C., and K.A. Buhlmann. 2007. Status of the Spotted Turtle (*Clemmys guttata*) in Virginia. Final Report to Virginia Department of Game and Inland Fisheries, Wildlife Diversity Section, Richmond, VA. 86 pp.

Mitsch, W.J. 2017. Solving Lake Erie's harmful algal blooms by restoring the Great Black Swamp in Ohio. Ecological Engineering 108: 406–413.

Mitsch, W.J., and J.G. Gosselink. 2015. Wetlands (5th ed.). John Wiley & Sons, Hoboken, NJ. 744 pp.

Mota, J.L. 2022. Assessment of the geographic distribution and tools to assist with conservation of Spotted Turtles (*Clemmys guttata*) in West Virginia. Thesis, West Virginia University, Morgantown, WV.

Mullin, D.D., R.C. White, A.M. Lentini, R.J. Brooks, K.R. Bériault, and J.D. Litzgus. 2020. Predation and disease limit population recovery following 15 years of headstarting an endangered freshwater turtle. Biological Conservation 245: 108496.

Muñoz, D.J., D.A.W Miller, C. Sutherland, and E.H.C. Grant. 2016. Using spatial capture–recapture to elucidate population processes and space-use in herpetological studies. Journal of Herpetology 50(4): 570–581.

Nagle, R.D., O.M. Kinny, J.W. Gibbons, and J.D. Congdon. 2017. A simple and reliable system for marking hard-shelled turtles: the North American code. Herpetological Review 48(2): 327–330.

Nagle, R.D., T.J. Russell, and R.J. Rimple. 2021. Sheltering oak: Spotted Turtles in a tree. Ecology, 103(2): e03585.

National Oceanic and Atmospheric Administration (NOAA). 2020. U.S. Climate Normals 2020: U.S. Monthly Climate Normals (1991-2020). https://www.ncei.noaa.gov

National Oceanic and Atmospheric Administration NOAA Office for Coastal Management. 2017. Detailed method for mapping sea level rise marsh migration. <https://coast.noaa.gov/data/digitalcoast/pdf/slr-marsh-migration-methods.pdf>. Accessed 29 Mar 2022.

National Oceanic and Atmospheric Administration NOAA Office for Coastal Management. 2022*a*. Digital coast sea level rise viewer: frequent questions. <https://coast.noaa.gov/data/digitalcoast/pdf/slr-faq.pdf>. Accessed 29 Mar 2022.

National Oceanic and Atmospheric Administration NOAA Office for Coastal Management. 2022*b*. Sea level rise wetland impacts and migration. <https://coast.noaa.gov/digitalcoast/data/slr-wetland.html>. Accessed 29 Mar 2022.

National Oceanic and Atmospheric Administration NOAA Office for Coastal Management. 2022*c*. C-CAP regional land cover and change. <https://coast.noaa.gov/digitalcoast/data/ccapregional.html>. Accessed 29 Mar 2022.

National Oceanic and Atmospheric Administration NOAA Office for Coastal Management. 2022*d*. Sea level rise viewer. <https://coast.noaa.gov/digitalcoast/tools/slr.html>. Accessed 29 Mar 2022.

NatureServe. 2002. Element Occurrence Data Standard.

NatureServe. 2016. NatureServe Explorer [web application]. NatureServe, Arlington, Virginia. <https://explorer.natureserve.org/>. Accessed 13 Jan 2022.

Neil, W.T. 1958. The occurrence of amphibians and reptiles in saltwater areas and a bibliography. Bulletin of Marine Science of the Gulf and Caribbean 8(1): 1–97.

Newman, K., S.T Buckland, B.J. Morgan, R. King, D. Borchers, D.J Cole, P. Besbeas, O. Gimenez, and L. Thomas. 2014. Modelling population dynamics. Springer Press, New York.

Nikitina, D.L., A.C. Kemp, B.P. Horton, C.H. Vane, O. van de Plassche, and S.E. Engelhart. 2014. Storm erosion during the past 2000 years along the north shore of Delaware Bay, USA. Geomorphology 208: 160–172.

O'Bryan, C. J., M.H. Holden, and J.E.M. Watson. 2019. The mesoscavenger release hypothesis and implications for ecosystem and human well-being. Ecology Letters 22(9): 1340–1348.

O'Bryan, C.J. 2014. Persistence of a vulnerable semi-aquatic turtle in an intensively-managed forest landscape. M.Sc. thesis, Wildlife and Fisheries Biology, Clemson University, Clemson, South Carolina.

O'Bryan, C.J., J.A. Homyack, R.F. Baldwin, Y. Kanno, and A.L. Harrison. 2016. Novel habitat use supports population maintenance in a reconfigured landscape. Ecosphere 7(3): 1–15.

O'Dell, D.I., J.M. Karberg, K.C. Beattie, K.A. Omand, and E.C. Buck. 2021. Changes to Spotted Turtles (*Clemmys guttata*) habitat selection in response to a salt marsh restoration. Wetlands Ecology and Management, 29(2): 301–313.

Ontario Ministry of the Environment, Conservation and Parks. 2019. Recovery strategy for the Spotted Turtle (*Clemmys guttata*) in Ontario. Ontario Recovery Strategy Series. Prepared by the Ministry of the Environment, Conservation and Parks, Peterborough, Ontario. iv + 5 pp. + Appendix. Adoption of the Recovery Strategy for Spotted Turtle (*Clemmys guttata*) in Canada (Environment and Climate Change Canada 2018). 1–83.

Ossiboff, R.J., B.L. Raphael, A.D. Ammazzalorso, T.A. Seimon, A.L. Newton, T.Y. Chang, B. Zarate, A.L. Whitlock, and D. McAloose. 2015*b*. Three novel herpesviruses of endangered Clemmys and Glyptemys turtles. PLoS one 10(4): e0122901.

Ossiboff, R.J., B.L. Raphael, A.D. Ammazzalorso, T.A. Seimon, H. Niederriter, B. Zarate, A.L. Newton, and D. McAloose. 2015*a*. A Mycoplasma species of Emydidae turtles in the northeastern USA. Journal of Wildlife Diseases 51(2): 466–470.

Oxenrider, K.J., B.M. Heres, and D.J. Brown. 2018. *Clemmys guttata* (Spotted Turtle) habitat use. Herpetological Review 49(3): 525–526.

Oxenrider, K.J., B.M. Heres, J.L. Mota, and D.J. Brown. 2019. Influence of bait type on capture success of *Clemmys guttata* and *Chrysemys picta* using small hoop nets in shallow wetlands. Herpetological Review 50(3): 490–492.

Parker, P.G., and H.H. Whiteman. 1993. Genetic diversity in fragmented populations of *Clemmys guttat*a and *Chrysemys picta marginata* as shown by DNA fingerprinting. Copeia. 1993(3): 841–846.

Paton, P.W. 1994. The effect of edge on avian nest success: how strong is the evidence?. Conservation Biology 8(1): 17–26.

Perillo, K.M. 1997. Seasonal movements and habitat preferences of Spotted Turtles (*Clemmys guttata*) in north central Connecticut. Chelonian Conservation and Biology 2:445–446.

Platt, S.G., J.L. Smith, T.R. Rainwater, and W.J. Boeing. 2019. Notes on the predation of Rough-footed Mud Turtles (*Kinosternon hirtipes*) in west Texas, USA. Western North American Naturalist 79(1): 130–134.

Pollock, K.H. 1982. A capture-recapture design robust to unequal probability of capture. Journal of Wildlife Management 46(3): 752–757.

Pollock, K.H., J.D. Nichols, C. Brownie, and J.E. Hines. 1990. Statistical inference for capture–recapture experiments. Wildlife Monographs 107: 3–97.

Poloczanska, E.S., C.J. Limpus, and G.C. Hays. 2009. Vulnerability of marine turtles to climate change. Advances in Marine Biology 56: 151–211.

Powell, R., R. Conant, and J.T. Collins. 2016. Peterson field guide to reptiles and amphibians of eastern and central North America. Fourth edition. Mariner Books, New York, NY.

Prange, S., S.D. Gehrt, E.P. Wigger. 2004. Influences of anthropogenic resources on raccoon (*Procyon lotor*) movements and spatial distribution. Journal of Mammalogy 85(3): 483–490.

PRISM Climate Group. 2010*a*. Minimum, maximum, and mean temperature. Oregon State University. <http://prism.oregonstate.edu>. Accessed 28 July 2017.

PRISM Climate Group. 2010*b*. Annual precipitation. Oregon State University. <http://prism.oregonstate.edu>. Accessed 28 July 2017.

PRISM Climate Group. Oregon State University. <https://prism.oregonstate.edu>. Accessed April 2021

Quintero, I., and J.J. Wiens. 2013. Rates of projected climate change dramatically exceed past rates of climatic niche evolution among vertebrate species. Ecology Letters 16(8): 1095–1103.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.

Rasmussen, M.L. 2009. Habitat selection, foraging ecology, and maternal investment in a Lake Heron population of Spotted Turtles (*Clemmys guttata*): implications for conservation management. M.Sc. Thesis. Laurentian University, Sudbury, Ontario.

Rasmussen, M.L., and J.D. Litzgus. 2010*a*. Patterns of maternal investment in Spotted Turtles (*Clemmys guttata*): Implications of trade-offs, scales of analyses, and incubation substrates. Ecoscience 17(1): 47–58.

Rasmussen, M.L., and J.D. Litzgus. 2010*b*. Habitat selection and movement patterns of Spotted Turtles (*Clemmys guttata*): effects of spatial and temporal scales of analyses. Copeia (1): 86–96.

Ream, C., and R. Ream. 1966. The influence of sampling methods on the estimation of population structure in Painted Turtles. The American Midland Naturalist 75(2): 325–338.

Redford, K.H., G. Amato, J. Baillie, P. Beldomenico, E.L. Bennett, N. Clum, R. Cook, G. Fonseca, S. Hedges, F. Launay, S. Lieberman, G.M. Mace, A. Murayama, A. Putnam, J.G. Robinson, H. Rosenbaum, E.W. Sanderson, S.N. Stuart, P. Thomas, and J. Thorbjarnarson. 2011. What does it mean to successfully conserve a (vertebrate) species?. BioScience 61(1): 39–48.

Reeves, D.J., and J.D. Litzgus. 2008. Demography of an island population of Spotted Turtles (*Clemmys guttata*) at the species northern range limit. Northeastern Naturalist 15(3): 417–430.

Refsnider, J.M., S.E. Carter, A. Diaz, A.C. Hulbert, G.R. Kramer, P. Madden, and H.M. Streby. 2022. Macro- and microhabitat predictors of nest success and hatchling survival in Eastern Box Turtles (*Terrapene carolina carolina*) and Spotted Turtles (*Clemmys guttata*) in oak savanna landscapes. Frontiers in Ecology and Evolution 9: 788025.

Reid, B.N., and M.Z. Peery. 2014. Land use patterns skew sex ratios, decrease genetic diversity and trump the effects of recent climate change in an endangered turtle. Diversity and Distributions 20(12): 1425–1437.

Rhodes, L., M. McHugh, and T. Gruszkos. 2019. Inland and coastal wetlands of Massachusetts: status and trends. Massachusetts Department of Environmental Protection, Boston, MA. 40 pp.

Ritchie, E.G., and C.N. Johnson. 2009. Predator interactions, mesopredator release and biodiversity conservation. Ecology Letters 12(9): 982–998.

Rivest, L.P., and T. Lévesque. 2001. Improved log-linear model estimators of abundance in capture-recapture experiments. Canadian Journal of Statistics 29(4): 555–572.

Roberts, H.P., M.T. Jones, L.L. Willey, T.S.B. Akre, P.R. Sievert, P. deMaynadier, K.D. Gipe, G. Johnson, J. Kleopfer, M. Marchand, J. Megyesy, S. Parren, E. Thompson, C. Urban, D. Yorks, B. Zarate, L. Erb, A.M. Ross, J. Dragon, L. Johnson, E. Lassiter, and E. Lassiter. 2021. Large-scale collaboration reveals landscape-level effects of land-use on turtle demography. Global Ecology and Conservation 30: e01759.

Robillard, A.J., S. Robinson, E. Bastiaans, and D. Vogler. 2019. Impacts of a highway on the population genetic structure of a threatened freshwater turtle (*Glyptemys insculpta*). Amphibian & Reptile Conservation 13(2): 267–275.

Rocker, A.M. 2021. Snack-sized turtles? Investigating size class distributions and predation of the endangered Spotted Turtle (*Clemmys guttat*a). M.Sc. Thesis. Salisbury University, Salisbury, Maryland, USA.

Royle, J.A. 2004. N-mixture models for estimating population size from spatially replicated counts. Biometrics 60(1): 108–115.

Royle, J.A., M. Kéry, and J. Guélat. 2011. Spatial capture-recapture models for search-encounter data. Methods in Ecology and Evolution 2(6): 602–61

Royle, J.A., and R.M. Dorazio. 2008. Hierarchical modeling and inference in ecology: the analysis of data from populations, metapopulations and communities. Academic Press, San Diego, California, USA.

Safi, A., M.U.A. Hashmi, and J.P. Smith. 2020. A review of distribution, threats and conservation of freshwater turtles of Ontario, Canada. SPC Journal of Environmental Sciences 2(1): 36–41.

Santilli, J., and N. Rollison. 2018. Toward a general explanation for latitudinal clines in body size among chelonians. Biological Journal of the Linnean Society 124(3): 381–393.

Schmidt, S.R. 2003. Reptile cholinesterase characterization and use in monitoring anti-cholinesterases. M.Sc. Thesis. Texas Tech University, Lubbock, Texas, USA.

Schneider, J.G. 1792. Beschreibung und Abbildung einer neuen Art von Wasserschildkröte nebst Bestimmungen einiger bisher wenig bekannten fremden Arten. Schriften der Gesellschaft Naturforschender Freunde zu Berlin 10: 259–283.

Schwanz, L.E., R.J. Spencer, R.M. Bowden, and F.J. Janzen. 2010. Climate and predation dominate juvenile and adult recruitment in a turtle with temperature-dependent sex determination. Ecology 91(10): 3016–3026.

Schwartz, F.J. 1961. Maryland turtles. Maryland Department Research & Education Service 50: 1–44.

Seber, G.A.F. 1992. A review of estimating animal abundance II. International Statistical Review 60(2): 129–166.

Seburn, D.C. 2003. Population structure, growth, and age estimation of Spotted Turtles, *Clemmys guttata*, near their northern limit: an 18-year follow-up. The Canadian Field Naturalist 117(3): 436–439.

Seburn, D.C. 2012. Why didn't the Spotted Turtle (*Clemmys guttata*) cross the road? Herpetology Notes 5: 527–530.

Selwood, K.E., M.A. McGeoch, and R. Mac Nally. 2015. The effects of climate change and land-use change on demographic rates and population viability. Biological Reviews 90(3): 837–853.

Semlitsch, R. D., and J. R. Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology 17(5): 1219–1228.

Shaffer, M., and B. Stein. 2000. Safeguarding our precious heritage. Pages 301–322 *in*. Precious Heritage: The Status of Biodiversity in the United States. Oxford University Press.

Sinervo, B., F. Méndez-de-la-Cruz, D.B. Miles, B. Heulin, E. Bastiaans, M. Villagrán-Santa Cruz, R. Lara-Resendiz, N. Martínez-Méndez, M.L. Calderón-Espinosa, R.N. Meza-Lázaro, H. Gadsden. 2010. Erosion of lizard diversity by climate change and altered thermal niches. Science 328(5980): 894–899.

Smart, L.S., J. Vukomanovic, E.O. Sills, and G. Sanchez. 2021. Cultural ecosystem services caught in a ‘coastal squeeze’ between sea level rise and urban expansion. Global Environmental Change 66: 102209.

Smith, D., N. Allan, C. McGowan, J. Szymanski, S. Rogers-Oetker, and H. Bell. 2018. Development of a species status assessment process for decisions under the U.S. Endangered Species Act. Journal of Fish and Wildlife Management 9(1): 302–320.

Smith, G.S., and R.W. Tiner. 1993. Status and trends of wetlands in Cape May County, New Jersey and vicinity (1977 to 1991). U.S. Fish and Wildlife Service, Hadley, MA. Cooperative Report R-93/13, 38 pp.

Soga, M., and K.J. Gaston. 2018. Shifting baseline syndrome: causes, consequences, and implications. Frontiers in Ecology and the Environment 16(4): 222–230.

Spencer, R.J., and M.B. Thompson. 2005. Experimental analysis of the impact of foxes on freshwater turtle populations. Conservation Biology 19(3): 845–854.

Spinks, P.Q., G.B. Pauly, J.J. Crayon, and H.B. Shaffer. 2003. Survival of the Western Pond Turtle (*Emys Marmorata*) in an urban California environment. Biological Conservation 113(2): 257–267.

Stedman, S., and T.E. Dahl. 2008. Status and trends of wetlands in the coastal watersheds of the eastern United States 1998 to 2004. National Oceanic and Atmospheric Administration, National Marine Fisheries Service and U.S. Department of the Interior, Fish and Wildlife Service. 32 pp.

Steen, D.A., and J.P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18(4): 1143–1148.

Stevenson, D.J., J.B. Jensen, E.A. Schlimm, and M. Moore. 2015. The distribution, habitat use, activity and status of the Spotted Turtle (*Clemmys guttata*) in Georgia. Chelonian Conservation and Biology 14(2): 136–142.

Stevenson, R.D. 1985. Body size and limits to the daily range of body temperature in terrestrial ectotherms. The American Naturalist 125(1): 102–117.

Storer, D.H. 1839. Reptiles of Massachusetts. In Reports on the Fishes, Reptiles, and Birds of Massachusetts. Dutton and Wentworth; Boston.

Stralberg, D., C. Carroll, J.H. Pedlar, C.B. Wilsey, D.W. McKenney, and S.E. Nielsen. 2018. Macrorefugia for North American trees and songbirds: climatic limiting factors and multi-scale topographic influences. Global Ecology and Biogeography 27(6): 690–703.

Sweet, W.V., B.D. Hamlington, R.E. Kopp, C.P. Weaver, P.L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A.S. Genz, J.P. Krasting, E. Larour, D. Marcy, J.J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K.D. White, and C. Zuzak. 2022. Global and regional sea level rise scenarios for the United States: updated mean projections and extreme water level probabilities along U.S. coastlines. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD, 111 pp.

Temple, S.A. 1987. Do predators always capture substandard individuals disproportionately from prey populations?. Ecology 68(3): 669–674.

Terwilliger Consulting, Inc. and the Northeast Fish and Wildlife Diversity Technical Committee. 2013. Southeastern Regional Species of Conservation Need (RSGCN).

<https://www.nwf.org/Our-Work/Wildlife-Conservation/southeast-regional-priority-species>

Tetzlaff, S.J., J.H. Sperry, B.A. Kingsbury, and B.A. DeGregorio. 2019. Captive-rearing duration may be more important than environmental enrichment for enhancing turtle head-starting success. Global Ecology and Conservation 20: e00797.

Therres, G.D. 1999. Wildlife species of regional conservation concern in the northeastern United States. Northeast Wildlife 54: 93–100.

Thompson, D., G. Glowacki, D. Ludwig, R. Reklau, A.R. Kuhns, C.K. Golba, and R. King. 2020. Benefits of head-starting for Blanding's Turtle size distributions and recruitment. Wildlife Society Bulletin 44(1): 57–67.

Thoreau, H.D. 2009. The Journal, 1837–1861. New York Review of Books; New York.

Thuiller, W., D. Georges, R. Engler., F. Breiner. 2016. biomod2: ensemble platform for species distribution modeling. R package version 3.3-7. <https://CRAN.R-project.org/package=biomod2>

Tiner, R.W. 1990. Pennsylvania's Wetlands: Current status and trends. U.S. Fish and Wildlife Service, Newton Center, MA. Prepared for the Pennsylvania Bureau of Water Resources Management, Division of Rivers and Wetlands Conservation, Harrisburg, PA. 112 pp.

Tiner, R.W. 2001. Delaware's Wetlands: Status and recent trends. U.S. Fish and Wildlife Service, Northeast Region, Hadley MA. Prepared for the Delaware Department of Natural Resources and Environmental Control, Watershed Assessment Section, Division of Water Resources, Dover, DE. Cooperative National Wetlands Inventory Publication. 19 pp.

Tiner, R.W. and D.B. Foulis. 1994*c*. Wetland status and trends in Charles County, Mayland (1981 to 1988–89). U.S. Fish and Wildlife Service, Hadley MA. Prepared for Maryland Department of Natural Resources, Water Resources Administration, Nontidal Wetlands Division, Annapolis, MD. 14 pp.

Tiner, R.W. and D.B. Foulis. 1994*a*. Wetland trends for selected areas of Dorchester County, Maryland and vicinity (1981–82 to 1988–89). U.S. Fish and Wildlife Service, Hadley MA. Prepared for U.S. Fish and Wildlife Service, Chesapeake Bay Estuary Program and U.S. Environmental Protection Agency, Annapolis, MD. 22 pp.

Tiner, R.W. and W. Zinni, Jr. 1988. Recent Wetland Trends in Southeastern Massachusetts. U.S. Fish and Wildlife Service, Newton Corner, MA. Prepared for U.S. Army Corps of Engineers, New England Division, Waltham, MA. 12 pp.

Tiner, R.W., and D.B. Foulis. 1992*a*. Recent wetland trends in Anne Arundel County, Maryland (1981–82 to 1988–90). U.S. Fish and Wildlife Service, Newton Corner, MA. Prepared for Maryland Department of Natural Resources, Water Resources Administration, Nontidal Wetlands Division, Annapolis, MD. 18 pp.

Tiner, R.W., and D.B. Foulis. 1992*b*. Wetland trends in Prince Georges County, Mayland (1981 to 1988–89). U.S. Fish and Wildlife Service, Hadley MA. Prepared for Maryland Department of Natural Resources, Water Resources Administration, Nontidal Wetlands Division, Annapolis, MD. 21 pp.

Tiner, R.W., and D.B. Foulis. 1994*b*. Wetland status and trends in Calvert County, Mayland (1981–82 to 1988–89). U.S. Fish and Wildlife Service, Hadley MA. Prepared for Maryland Department of Natural Resources, Water Resources Administration, Nontidal Wetlands Division, Annapolis, MD. 14 pp.

Tiner, R.W., D.B. Foulis, C. Nichols, S. Schaller, D. Petersen, K. Andersen, and J. Swords. 1998. Wetland status and trends for the Neponset Watershed, Massachusetts (1977–1991). U.S. Fish and Wildlife Service, Hadley MA and University of Massachusetts, Department of Plant and Soil Sciences, Amherst, MA. Prepared for Massachusetts Department of Environmental Protection, Bureau of Resource Protection, Worcester, MA and U.S. Army Corps of Engineers, Concord, MA. 32 pp.

Tiner, R.W., J.Q. Swords, and B.J. McClain. 2002. Wetland status and trends for the Hackensack Meadowlands. U.S. Fish and Wildlife Service, Hadley, MA. Assessment Report for U.S. Fish and Wildlife Service's National Wetlands Inventory Program, Washington D.C. 34 pp.

Tiner, R.W., J.Q. Swords, and H.C. Bergquist. 2005. Recent wetland trends in Southeastern Virginia: 1994–2000. U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA. NWI Wetland Trends Report. 17 pp.

*Tiner, R.W., K. McGuckin, and J. Herman. 2013. Changes in Connecticut wetlands: 1990 to 2010. Prepared for the State of Connecticut, Department of Energy and Environmental Protection, Hartford, CT. U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA. 30 pp.

Tiner, R.W., M.A. Biddle, A.D. Jacobs, A.B. Rogerson, and K.G. McGuckin. 2011. Delaware wetlands: Status and changes from 1992 to 2007. U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA and the Delaware Department of Natural Resources and Environmental Control, Dover, DE. Cooperative National Wetlands Inventory Publication. 35 pp.

Tomillo, P.S., M. Genovart, F.V. Paladino, J.R. Spotila, and D. Oro. 2015. Climate change overruns resilience conferred by temperature-dependent sex determination in sea turtles and threatens their survival. Global Change Biology 21(8): 2980–2988.

U.S. Attorney's Office District of New Jersey. 2015. Jersey City, New Jersey, man sentenced to five years of probation for trafficking threatened turtles. United States Department of Justice. <https://www.justice.gov/usao-nj/pr/jersey-city-new-jersey-man-sentenced-five-years-probation-trafficking-threatened-turtles>. Accessed 27 Apr 2022.

U.S. Attorney's Office District of Oregon. 2019. Chinese national pleads guilty to smuggling more than 300 endangered and vulnerable turtles from the U.S. to China. United States Department of Justice. <https://www.justice.gov/usao-or/pr/chinese-national-pleads-guilty-smuggling-more-300-endangered-and-vulnerable-turtles-us>. Accessed 27 Apr 2022.

U.S. Attorney's Office District of Oregon. 2021. California man pleads guilty for role in scheme to smuggle endangered and vulnerable turtles from the U.S. to China. United States Department of Justice. <https://www.justice.gov/usao-or/pr/california-man-pleads-guilty-role-scheme-smuggle-endangered-and-vulnerable-turtles-us>. Accessed 27 Apr 2022.

U.S. Attorney's Office District of South Carolina. 2015. Turtle traders sentenced for wildlife trafficking. United States Department of Justice. <https://www.justice.gov/usao-sc/pr/turtle-traders-sentenced-wildlife-trafficking>. Accessed 27 Apr 2022.

U.S. Attorney's Office Middle District of Georgia. 2022. Reptile dealer sentenced to prison for illegally trafficking animals, gun charges. United States Department of Justice. <https://www.justice.gov/usao-mdga/pr/reptile-dealer-sentenced-prison-illegally-trafficking-animals-gun-charges>. Accessed 27 Apr 2022.

U.S. Fish & Wildlife Service. 2020. National Wetlands Inventory website. U.S. Department of the Interior, Fish & Wildlife Service, Washington, D.C. <http://www.fws.gov/wetlands/>.

U.S. Geological Survey (USGS). 2009. 3D Elevation Program Digital Elevation Model. <https://www.usgs.gov/the-national-map-data-delivery >.

U.S. Geological Survey (USGS) GAP Analysis Project. 2018. Protected Areas Database of the United States (PAD-US): U.S. Geological Survey data release. <https://doi.org/10.5066/P955KPLE>.

U.S. Geological Survey (USGS) GAP Analysis Project. 2020. Protected Areas Database of the United States (PAD-US) 2.1: U.S. Geological Survey data release. <https://doi.org/10.5066/P92QM3NT>.

UNEP-WCMC (Comps.) [2022*a*]. The Checklist of CITES Species Website. CITES Secretariat, Geneva, Switzerland. Compiled by UNEP-WCMC, Cambridge, UK. <http://checklist.cites.org>. Accessed: 25 Apr 2022.

UNEP-WCMC (Comps.) [2022*b*]. CITES Trade Database. CITES Secretariat, Geneva, Switzerland. Compiled by UNEP-WCMC, Cambridge, UK. <https://trade.cites.org/>. Accessed: 25 Apr 2022.

Ury, E.A., X. Yang, J.P. Wright, and E.S. Bernhardt. 2021. Rapid deforestation of a coastal landscape driven by sea-level rise and extreme events. Ecological Applications 31(5): e02339.

USA National Phenology Network. 2020. Accumulated Growing Degree Days – 50 Base Temp for United States USA-NPN, Tucson, Arizona, USA. Dataset Accessed 2021 at <http://dx.doi.org/10.5066/F7SN0723>.

USDA-NASS. 2019. USDA National Agricultural Statistics Service Cropland Data Layer. Published crop-specific data layer [Online]. Washington D.C. <https://nassgeodata.gmu.edu/CropScape/>. Accessed 10 Jul 2020.

USFWS Office of Law Enforcement. 2016. Accomplishments 2015. United States Fish and Wildlife Service, Falls Church, VA. <https://www.fws.gov/sites/default/files/documents/OLE%20Annual%20Report%20fy-2015.pdf>. Accessed 25 Apr 2022.

USFWS Office of Law Enforcement. 2017. Accomplishments 2016. United States Fish and Wildlife Service, Falls Church, VA. <https://www.fws.gov/sites/default/files/documents/OLE%20Annual%20Report%20fy-2016.pdf>. Accessed 25 Apr 2022.

USFWS Office of Law Enforcement. 2020. Accomplishments 2018. United States Fish and Wildlife Service, Falls Church, VA.

<https://www.fws.gov/sites/default/files/documents/OLE%20Annual%20Report%20fy-2018.pdf>. Accessed 25 Apr 2022

Van Dam, B., J.D. Soule, and G. Hammerson. 2010. NatureServe Explorer: Spotted Turtle (*Clemmys guttata*). <https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.100580/Clemmys_guttata>. Accessed 1 Mar 2020.

van Dijk, P. P. 2010. IUCN Red List of Threatened Species: Spotted Turtle. IUCN Red List of Threatened Species. <https://www.iucnredlist.org/en>. Accessed 2 Jun 2020.

Walters, D.C., and M.L. Kirwan. 2016. Optimal hurricane overwash thickness for maximizing marsh resilience to sea level rise. Ecology and Evolution 6(9): 2948–2956.

Wang, P., and M.H. Horwitz. 2007. Erosional and depositional characteristics of regional overwash deposits caused by multiple hurricanes. Sedimentology 54(3): 545–564.

Ward, F.P., C.J. Hohmann, J.F. Ulrich, and S.E. Hill. 1976. Seasonal microhabitat selections of Spotted Turtles (*Clemmys guttata*) in Maryland elucidated by radioisotope tracking. Herpetologica 32(1): 60–64.

Warren, D.L., R.E. Glor, and M. Turelli. 2008. Environmental niche equivalency versus conservatism: quantitative approaches to niche evolution. Evolution: International Journal of Organic Evolution 62(11): 2868–2883.

Wheatley, M., and C. Johnson. 2009. Factors limiting our understanding of ecological scale. Ecological Complexity 6(2): 150–159.

Wickham, H. 2016. ggplot2: elegant graphics for data analysis. Springer-Verlag New York.

Wilbur, H.M. 1975. The evolutionary and mathematical demography of the turtle *Chrysemys picta*. Ecology 56(1): 64–77.

Willey, L.L., and M.T. Jones. 2014. Conservation plan for the Blanding's Turtle and associated species of conservation need in the northeastern United States. New Hampshire Fish & Game Department and the U.S. Fish & Wildlife Service.

Willey, L.L., M.T. Jones, P.R. Sievert, T.S. Akre, M. Marchand, P. deMaynadier, D. Yorks, J. Mays, J. Dragon, L. Erb, B. Zarate, et al. 2022. Distribution models combined with standardized surveys reveal widespread habitat loss in a threatened turtle species. Biological Conservation 266: 109437.

Wilson, M.F.J., B. O'Connell, C. Brown, J.C. Guinan, and A.J. Grehan. 2007. Multiscale terrain analysis of multibeam bathymetry data for habitat mapping on the continental slope. Marine Geodesy 30(1-2): 3–35.

Wilson, T.P. 1994. Ecology of the Spotted Turtle, *Clemmys guttata,* at the western range limit. M.Sc. Thesis, Eastern Illinois University, Charleston, Illinois, USA.

Wilson, T.P. 1999. Habitat change detection in an isolated population of Spotted Turtles in northern Virginia: concepts and applications. Conservation and Ecology of Turtles of the Mid-Atlantic Proceedings: 43–50.

World Wildlife Fund. 2016. Living planet report 2016: risk and resilience in a new era. WWF International, Gland, Switzerland.

Wright, J.O. 1907. Swamp and overflowed lands in the United States: Ownership and Reclamation. U.S. Department of Agriculture, Washington Government Printing Office. 26 pp.

Xiaoge, X.I.N., W.E.I. Min, L.I. Qingquan, Z.H.O.U. Wei, L.U.O. Yong, and Z.H.A.O. Zongci. 2019. Decadal prediction skill of BCC-CSM1.1 with different initialization strategies. Journal of the Meteorological Society of Japan: 97(3): 733–744.

Yagi, K.T. and J.D. Litzgus. 2012. The effects of flooding on the spatial ecology of Spotted Turtles (*Clemmys guttata*) in a partially mined peatland. Copeia 2: 179–190.

Yagi, K.T., and J.D. Litzgus. 2013. Thermoregulation of Spotted Turtles (*Clemmys guttata*) in a beaver-flooded bog in southern Ontario, Canada. Journal of Thermal Biology 38(5): 205–213.

Yang, L., S. Jin, P. Danielson, C.G. Homer, L. Gass, S.M. Bender, A. Case, C. Costello, J.A. Dewitz, J.A. Fry, M. Funk, B.J. Granneman, G.C. Liknes, M.B. Rigge, and G. Xian. 2018. A new generation of the United States National Land Cover Database—Requirements, research priorities, design, and implementation strategies: ISPRS Journal of Photogrammetry and Remote Sensing 146: 108–123.

Zeller, K.A., K. McGarigal, P. Beier, S.A. Cushman, T.W. Vickers, W.M. Boyce. 2014. Sensitivity of landscape resistance estimates based on point selection functions to scale and behavioral state: pumas as a case study. Landscape Ecology 29(3): 541–557.

Zeller, K.A., T.W. Vickers, H.B. Ernest, and W.M. Boyce. 2017. Multi-level, multi-scale resource selection functions and resistance surfaces for conservation planning: Pumas as a case study. PLoS One 12(6): e0179570.

Appendices

Appendix 1-A
Expert Evaluation of Threats

Jessica R. Meck, Lisabeth L. Willey, Michael T. Jones, and H. Patrick Roberts

To identify, rank, and characterize the perceived relative severity of threats to Spotted Turtle populations, we developed and circulated two expert polls, described below:

Survey of Threats

We conducted a targeted survey of Spotted Turtle experts throughout the eastern United States between January and April 2019. Experts were asked to evaluate a list of potential threats to Spotted Turtle populations, scoring each threat from 1 (very low) to 5 (very high). We received 23 responses with at least one response from each eastern state. Respondents reported an average of 11 years of experience studying Spotted Turtle populations.

Experts reported that the highest-ranked threats were as follows: development, habitat loss, and roads. Other high-ranking threats included: human-subsidized depredation, collection/poaching, lack of connectivity, lack of distributional information, and altered hydrology. The lowest-ranked threats were beaver activity and invasive plants (Figure1A-1). The most commonly referenced invasive plant of concern was common reed (*Phragmites australis*), listed by nine of the 23 (39%) respondents. Experts reported uncertainty about the effects of climate change, and over 50% of respondents noted uncertainty regarding the effects of climate change on Spotted Turtle populations.

Additional threats that were listed by experts in response to an open-ended question included ecological successional changes, water quality (pollution and sedimentation), lack of public awareness, and insufficient regulation. The most urgent areas of research were improving distributional information and obtaining better population size and trend data, with 13 of 23 (57%) respondents identifying these gaps.

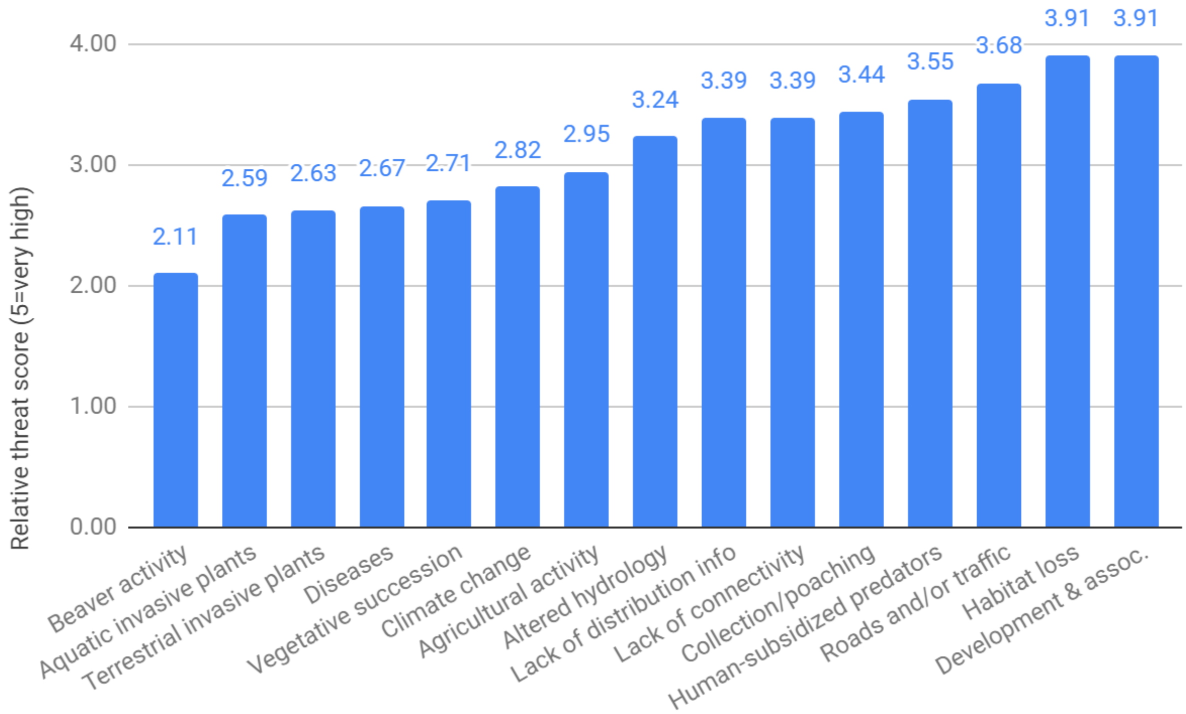


Figure 1A-1. Summary of threats ranked by Spotted Turtle experts in the eastern United States in 2019.

Regional Symposium Survey

As part of this conservation planning effort, we held a Spotted, Blanding's and Wood Turtle Conservation Symposium November 3–5, 2019 at the Cacapon Resort State Park in Berkeley Springs, West Virginia. Over 130 turtle managers and scientists from 78 institutions participated, sharing their knowledge and building partnerships to support the conservation of the Spotted Turtle and related emydine species. Forty-eight experts gave presentations on conservation planning, monitoring and management techniques, genetics, and combating illegal collection. A keynote lecture was provided by Dr. Jacqueline Litzgus of Laurentian University in Sudbury, Ontario.

Following the symposium, we sent an electronic survey to participants and other experts who were unable to attend the symposium in person to 1) identify and rank the severity of threats to the Spotted Turtle (and also Blanding's and Wood Turtles, though these species are beyond the scope of this Plan) across their range, and 2) prioritize conservation actions in future conservation and management decisions. Here we summarize the results of this survey for Spotted Turtles across their range, with regional subdivisions where helpful or appropriate. Though the focal geography of this Conservation Plan is the eastern United States, the symposium and survey were range-wide, providing helpful context and relevant information for conserving the eastern populations.

Respondents indicated their perception that the most significant threat to Spotted Turtle populations is habitat loss with illegal collection and elevated adult mortality ranked second and third, respectively (Figure 1A-2). The top-ranked conservation actions needed were identified as land protection followed by addressing illegal collection. However, over 30% of respondents indicated that additional information is needed to assess the potential impact of three threats: climate change, impaired reproduction/recruitment, and genetic isolation/inbreeding (Table 1A-1).

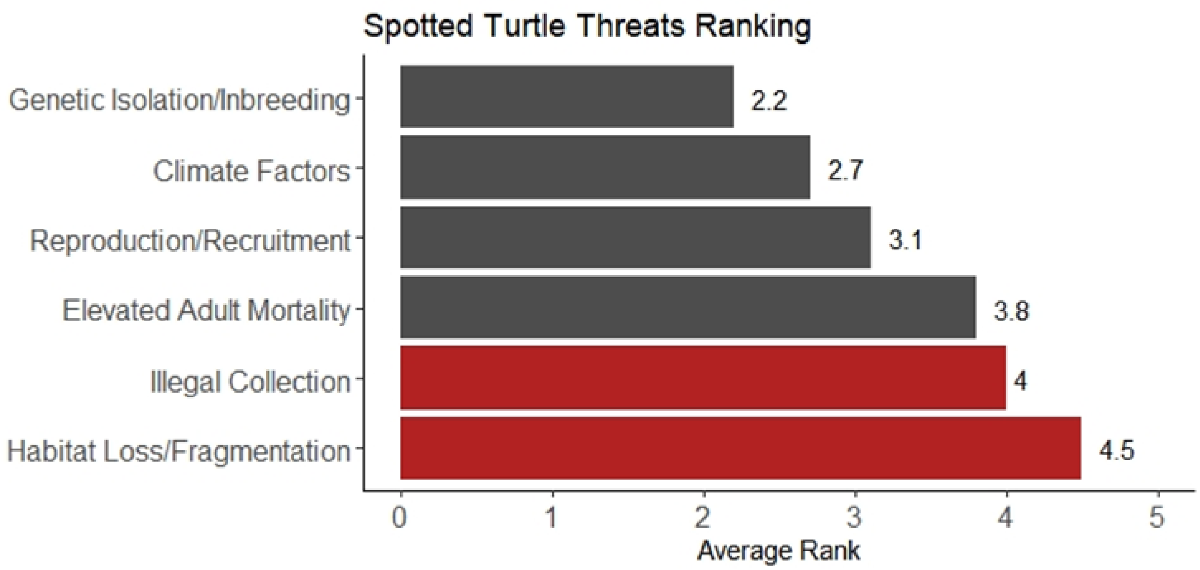


Figure 1A-2. The average ranked threats on a scale of 0 (not a threat) to 5 (major threat) for Spotted Turtles by all respondents range-wide.

Table 1A-1. The percent of respondents that indicated **'unsure or not enough information'** for each threat.

	Habitat Loss or Fragmentation	Illegal Collection	Adult Mortality	Genetic Isolation or Inbreeding	Reproduction or Recruitment Failure	Climate Factors
Percent	7%	18%	22%	31%	32%	32%

Regional Variation in Threats

Responses varied across the region, however (Table 1A-2). Respondents indicated in the open-ended questions that many data gaps exist for Spotted Turtles in the Southeast, including South Carolina, that inhibit researchers' understanding of the most pressing threats. Additionally, the relative influence of ditch management by mosquito control agencies—as well as in the context of forestry and cranberry operations—needs further evaluation in the field.

Table 1A-2. The average ranking for each threat, regionally from 0 (not a threat) to 5 (major threat).

Threat	Northeast (n=40)	Southeast (n=7)	Midwest (n=7)	Canada (n=10)
Climate Factors	2.8	2.2	2.2	3
Elevated Adult Mortality	3.9	3	4	3.6
Genetic Isolation and/or Inbreeding	2.2	1.8	2.7	2.4
Habitat Loss/Fragmentation	**4.6**	**3.7**	4.4	**4.5**
Illegal Collection	4	3.4	**4.5**	4.1
Reproduction and/or Recruitment Failure	3.5	1.5	3	2.3

Conservation Actions Needed

Land protection and **curtailing illegal collection** were ranked as the most important actions needed to maintain viable populations of Spotted Turtles range-wide (Figure 1A-3). The least important actions ranked were population management, nest protection, and predator control. The Midwest region (n=7 responses) indicated that nest protection and predator control were the third most needed actions with addressing illegal collection and land management ranking similarly, but land protection ranking highest. Priorities of the various actions also varied across the region (Table 1A-3).

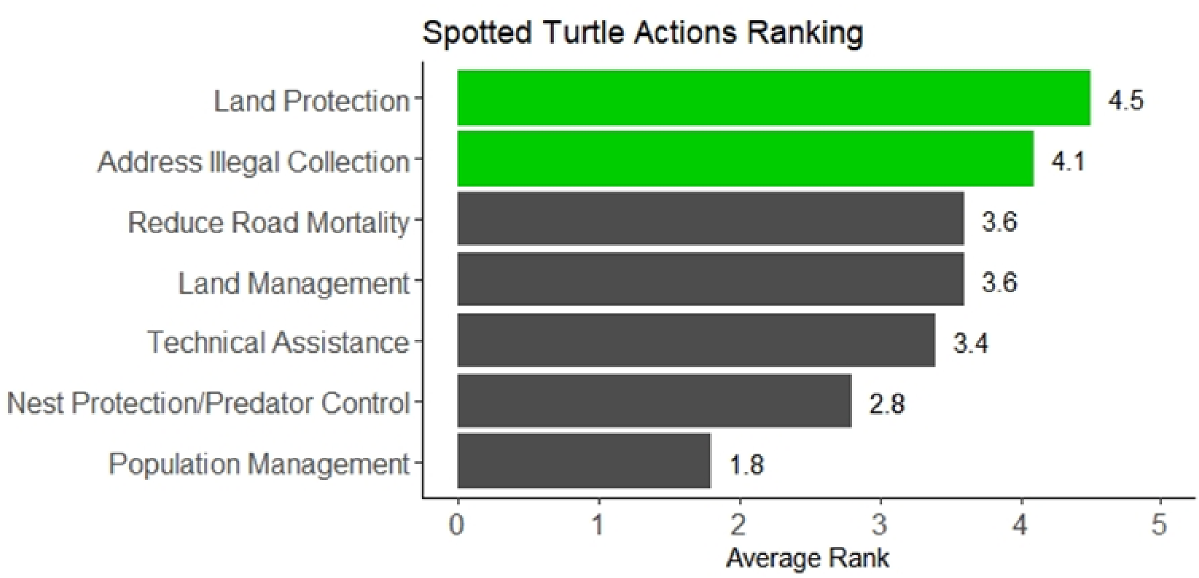


Figure 1A-3. The average ranking of conservation actions needed for Spotted Turtles on a scale of 0 (unimportant) to 5 (very important) from all respondents range-wide.

Table 1A-3. The average ranking for each action by region.

Action	Northeast (n=40)	Southeast (n=7)	Midwest (n=7)	Canada (n=10)
Address Illegal Collection	**4.2**	**4.3**	4.1	4.2
Land Management	3.7	2.6	4	3.6
Land Protection	4.6	4	**4.9**	**4.5**
Nest Protection/ Predator Control	2.9	1.4	4.1	2.2
Population Management	1.9	1	2.1	2.2
Reduce Road Mortality	3.8	3.3	3.1	3.5
Technical Assistance	3.6	2.3	3.1	3.3

Future Collaboration

Participants were also in favor of a third conservation symposium and ranked it as the top inter-regional coordination action item with actively expanding partnerships ranked second. A C-SWG-funded Wood Turtle conservation symposium is planned to occur in 2023 to support the conservation needs of Wood Turtles and related emydidae species, including Spotted Turtles.

Appendix 4-A.
Regional Spotted Turtle Assessment Protocol

Eastern Spotted Turtle Working Group[2]

Supported in part by State Wildlife Grants
through the USFWS Competitive State Wildlife Grants Program
and the Northeast Regional Conservation Needs (RCN) Program
www.northeastturtles.org

Updated: March 24, 2019

This document outlines a standardized and flexible methodology for sampling Spotted Turtle (*Clemmys guttata*) populations in the eastern part of the species' range (Maine to Florida). This protocol is adapted in part from the Northeast Blanding's Turtle Sampling Protocol developed by the Northeast Blanding's Turtle Working Group (www.blandingsturtle.org) and funded by a US Fish and Wildlife Service Competitive State Wildlife Grant to the Virginia Department of Game and Inland Fisheries. The protocol was refined based upon an expert poll completed by experts from Maine to Florida and was updated in 2019 based on results from 2018 sampling.

Two basic methodologies are outlined: trap-based assessments and visual assessments without traps. Two levels of trap-based assessments—**Rapid** and **Demographic**—are described. The protocol for Rapid Assessments is simply a reduced-effort version of the Demographic Assessment protocol. A visual Rapid Assessment is also described. To summarize the protocol: (1) delineate potential Spotted Turtle habitat using a geographic information system (e.g., Google Earth or ArcGIS) and recent aerial imagery; (2) place up to four 200-m radius plots centered on potential Spotted Turtle habitat with plot centroids up to 800 m apart; (3) conduct a Trap-based Rapid Assessment (TRA), Demographic Assessment (DA; trap-based), or Visual Rapid Assessment (VRA). For TRAs, place five traps ≥30 m apart within the reference plots. Traps may be set anytime during the Spotted Turtle activity season in your region. Check all traps every 24 hours for four consecutive days. For DAs, conduct the TRA protocol three times (for a total of 12 nights). For VRAs, two types of assessments are possible—**time constrained** and **unconstrained**. In both cases, a single observer visits a site three times during the survey season and during each visit, actively searches for turtles on foot. For time constrained surveys, the surveyor searches for 20 minutes per reference plot (up to 80 minutes total per visit),

---

[2] For a list of partners and additional information, see: www.northeastturtles.org or www.americanturtles.org. Protocol development sub-group: Liz Willey (American Turtle Observatory [ATO] and Antioch University New England), Mike Jones (Massachusetts Division of Fisheries and Wildlife), Patrick Roberts (University of Massachusetts and ATO), Kat Lauer (Antioch University New England), Tom Akre (Smithsonian Conservation Biology Institute), Lori Erb (Mid-Atlantic Center for Herpetology and Conservation), Derek Yorks (Maine Department of Inland Fisheries and Wildlife), Jonathan Mays (Florida Fish and Wildlife Conservation Commission), and JD Kleopfer (Virginia Dept. of Game and Inland Fisheries). For questions, contact: info@americanturtles.org.

recording start and stop time and location of each survey. For unconstrained surveys, the surveyor walks a meandering transect anywhere within each reference plot, for as long as the survey takes, recording start and end time and GPS track.

The methodology outlined in this document is designed to be relatively simple, flexible, fit within existing research programs, and accommodate regional differences in seasonal activity period, habitat structure, and research priorities. Broad regional participation is encouraged to increase the size of the representative sample. Data collected through the regional effort are maintained in a centralized database at the American Turtle Observatory (www.americanturtles.org) for pooled analysis.

Planning Phase

Step 1: Select a wetland complex

Identify and delineate a wetland or wetland complex that is suitable for study. It may either be (A) an area known to be occupied by Spotted Turtles; (B) a data-deficient site with potentially suitable Spotted Turtle habitat; (C) randomly-selected areas of potential habitat and occurrence (to be added in Year 2; 2019). When selecting a wetland complex for surveys, remember that Spotted Turtles are associated with a *wide array* of wetland habitats that vary regionally including, but not limited to, emergent marshes, deciduous shrub swamps, forested wetlands, seasonal pools, sphagnum bogs and seeps, linear ditches and canals, floodplain forests, and beaver impoundments. Whenever possible, use leaf-off or spring season aerial images when determining plot locations, as they allow greater visibility when mapping small seasonal pools in deciduous forest habitats (Figure 1). In some cases, additional examination of leaf-on imagery may assist plot placement. Surveyors should confirm that property access is allowed by the landowner, and that the site has diverse wetland habitat suitable for Spotted Turtles, either through aerial photo interpretation or field reconnaissance. As an approximate guide, the focus area should be ≥800 m^2 and ≤2 km^2 (though if much larger, multiple groups of four reference plots could be delineated).

Step 2: Develop reference plots

Within the focus area, identify four reference points separated by 400 to 800 m using Google Earth or a similar GIS program (Figure 1). Reference points should be centered on areas of highly suitable Spotted Turtle habitat (i.e., high potential use wetlands). Points may fall either on constellations of small wetlands (e.g., seasonal pools) or on portions of a single large wetland. Delimit 200-m radius (see distance justification, below) circular plots around reference points. All sampling should be conducted within these circular plots. Although four plots are ideal for spatial replication and to adequately sample larger landscapes, surveyors may place fewer than the recommended four reference plots if there is not enough suitable habitat available or if access is unavailable.

Step 3: Conduct an optional reconnaissance site visit

If you have not visited the site already, consider conducting a reconnaissance visit to make sure that property access is feasible and that the study plots should not be re-situated. Use this visit to identify potentially ideal trap locations and locations for visual surveys.

Figure 1. Illustration of study site delineation in Google Earth. The yellow central dots illustrate Reference Points centered on areas of suitable (or potentially suitable) Spotted Turtle habitat, surrounded by reference plots with 200-m radius.

Survey Phase

Option 1: Conduct a Trap Assessment (Rapid or Demographic Assessment)

Trap Assessment Types

Trap-based sampling may take the form of either rapid or demographic assessments. These assessment types differ in intensity (i.e., trap nights), but utilize the same trapping methodology and are therefore directly comparable.

Rapid.—Trap-based Rapid Assessments (TRA) are intended to serve as a method for quickly collecting baseline occurrence and abundance information. TRAs require four consecutive nights of trapping at a site during the Spotted Turtle active period.

Demographic.—Long-Term Trap Assessments (DA) are a more intensive method intended to facilitate the collection of population information that will allow for more precise estimates of population size, age structure, sex ratios, and additional population information via mark recapture.

DA sites should be trapped for 3, 4-night trap runs (3 TRAs) for a total of at least 12 nights during the Spotted Turtle active season.

Trap Configuration

Within each of the four circular sampling plots, place five traps (recommended: ProMar TR-502 or TR-503 24or36"x12" collapsible turtle traps OR crab traps utilized in FL/GA, see equipment section, below) 0–200 m from the reference point at the plot centroid (20 traps total over the four reference plots) in high potential use areas, as determined by the researcher in accordance with expert opinion. Ideally, all five traps within a single reference plot should be the same trap type, though different reference plots could have different trap types. The five traps per sampling plot can be placed in any number of wetlands (e.g., one large wetland or as many as five small wetlands). Ideally, traps should be placed at least 30 m intervals (the average daily movement distance of females in the spring observed by Litzgus and Mosseau [2004*b*] in South Carolina, see movement justification, below) in different directions from the reference point (e.g., 30 m to NW; 60 m to NE, etc.); however, the configuration and wetlands and microhabitat will often preclude this strategy. In instances where the wetland configuration is a single linear feature (e.g., a ditch or canal), the traps may be placed in a line along the wetland, separated by at least 30 m, ideally. Emphasis should be placed on habitat suitability rather than strict adherence to these distance rules, but traps should be at least 15 m apart if 30 m is not possible.

Demographic, High Density Trapping.—At sites with low turtle density, low recapture rates, low trap success, or extremely narrow opportunities for detection, and where the recommended DA protocol described above would yield too few captures for a population estimate, researchers may choose to conduct high density trapping within 1 or more reference plots. At least 1 four-night run at four reference plots with the recommended trap density (5 traps / reference plot) should occur (so that results can be compared with other sites throughout the region). In addition to the initial four night trap-run (equivalent to a TRA), researchers can then place 10 traps in each reference plot (in 1 to 3 plots, if necessary) for the remaining 8 (or more) trap nights. All reference plots should receive the same number of traps each night and all trap sets and checks should be recorded on the *high density trapping forms*.

Trap Placement

Microhabitat.—Traps should be located within high potential use areas as follows:

- In shallow (≤0.2 m, <trap diameter) flow channels that may direct movement of individuals
- At the edge of thick vegetation (e.g., sedges, grasses, shrubs) or structure (e.g., logs, debris)
- Proximal to basking sites
- At sites with good solar exposure
- Surrounded by cover that conceals traps

Placement.—Traps should be placed by experienced researchers or researchers that have undergone training to ensure the safety of the animals. Traps should be firmly staked into the ground (e.g., with 4' plastic-wire coated tomato stakes) or affixed to adjacent structures (e.g., using rope) at two locations to prevent animals, wind, etc. from moving them. Enough slack should be present in the rope to accommodate rising water levels. The traps should be set so that turtles have adequate headspace to breathe. For ProMar traps, place 1–2 empty plastic bottles (16 oz, with caps on tight) within traps or pool noodles along the outside of traps to ensure breathing space. GPS coordinates should be recorded at each trap once they are placed, and traps should be flagged or marked in accordance with each researcher's preference, including the reference number and trap number. In locations where traps may be seen by the public (e.g., roadsides, boardwalks, etc.), traps can be inconspicuously labeled, instead, so as to not attract attention, but it is of paramount importance that the trap be locatable so that traps are checked every 24 hours to ensure the safety of the animals. On the day of trap deployment, complete the trap set-up field form including habitat suitability information. **Surveyors must watch forecast weather conditions and pull or monitor traps if heavy precipitation or flooding is expected**. During subsequent DA trap placements, traps should generally be placed in the same location as during the previous run, unless this is impossible due to changing water levels.

Trap Checks.—Traps should be checked every 24 hours. On each trap-check day, the trap-check field form should be completed, and the turtle individual field form should be completed for each Spotted Turtle captured in the trap (see protocol for processing individual turtles), including for turtles that have been captured before (recaptures). Traps should be baited with ~½ can of sardines in oil (e.g., Beach Cliff) and rebaited every 24 hours. If traps are baited with other forms of bait, please indicate this on the field form. Air temperature should be recorded once in each reference plot and water temperature at each trap. Air temperature should be measured in the shade. Water temperature should be measured 10 cm below the surface, adjacent to a trap. If a trap had malfunctioned for some reason (e.g., raccoon depredation), please indicate that on the field form. For additional details, see field-form instructions. If raccoon depredation has occurred or is suspected, the trap should be pulled or replaced with a hard-sided trap to ensure the safety of the animals.

Option 2: Conduct a Visual Rapid Assessment

Visual Rapid Assessments (VRA) serve as a second method of rapid assessment intended to facilitate population assessments in regions or terrain where trap-based assessments may not be feasible as well as in habitats and portions of the species range where trapping appears to be less effective. VRAs and trap assessments can be applied at the same site, but *time-constrained* VRAs and trap assessments generally should not occur at the same time. However, a researcher who wishes to conduct unconstrained VRAs during trap checks (or while setting traps) could do so by recording visual survey effort between traps using tracks and processing turtles visually encountered using the unconstrained VRA protocol described below.

A single VRA is made up of three separate visits to one site within a four-week window of time in the active survey season. VRAs consist of active searching for turtles within wetlands on foot. There are two main approaches to distributing time throughout a reference plot and recording information during a VRA: Time constrained surveys and unconstrained surveys.

Time Constrained

If you are conducting a time-constrained survey, a total of 20 minutes should be spent surveying each reference plot (for a total of 80 minutes for 4 reference plots) on a given day. The information to record for each survey depends on the configuration of the wetland in the reference plot.

Time Constrained 1: For small (<0.1 ha) seasonal wetlands, observers should record the location of the wetland using GPS and the start time of the survey. The survey should continue until the entire wetland has been searched by the observer (or the water becomes too cloudy for the survey to be effective), and the end time of the survey should be recorded. The surveyor can then move on to another wetland in the reference plot until a total of 20 minutes has been spent in the reference plot on that day.

*Time Constrained 2***:** For straight, linear wetland features (e.g., canals or ditches), the observer should record the start time and location (using GPS) of the survey and proceed to survey the linear wetland until either 20 minutes has elapsed, the entire segment of the wetland in the reference plot has been surveyed, or the water becomes too cloudy for the survey to be effective. The surveyor should then record the time and GPS location at the end of the survey and then move on to another wetland in the reference plot, if there are any, until a total of 20 minutes has been spent in the reference plot on that day.

*Time Constrained 3***:** For larger or amorphous wetlands that make up the majority or entirety of a reference plot, the observer records the time and GPS location of the start of the survey and surveys throughout the wetland, within the reference plot, until 20 minutes has elapsed, and the surveyor then records the time and location of the end of the survey.

For each of the time-constrained VRA approaches, each visit requires 20 minutes of active searching per reference plot for a total of 80 minutes of active searching throughout the site. If animals are processed during a survey, the clock should be stopped during processing. As noted above, the observer should keep track of the amount of time not spent actively searching for turtles (e.g., when handling turtles) per sampling plot, and GPS waypoints should be recorded at the beginning and end of each sampling plot survey. The observer should attempt to visit all wetlands within the sampling plot during the allotted 20-minute window.

Unconstrained VRA

Instead of spending 20 minutes/plot, a surveyor may choose an unconstrained visual survey approach. For this method, the surveyor records the starting time and location of a survey and begins recording a GPS track. The surveyor then conducts a visual survey on foot anywhere within a reference plot for as long as it takes to adequately sample the plot, regardless of wetland configuration (i.e., the surveyor may move between wetlands). At the end of the reference plot survey, the surveyor records the end location and time of the survey and any processing time that occurred during the survey time, and stores the GPS track for the survey, before moving on to the next reference plot. For unconstrained surveys, each reference plot should be surveyed 3 times.

Regardless of the approach selected (constrained or unconstrained), a VRA field form should be filled out for each site visit. Air and water temperature should be recorded once within each sampling plot.

Number of observers

For consistency and to avoid scaring turtles, we recommend that only one observer should perform each VRA site-visit, but subsequent visits should ideally be conducted by different observers to reduce observer-related bias. If two observers are in the field together, we suggest they conduct surveys in different reference plots. For example, on survey day 1, observer 1 could sample plots 1 and 2 and observer 2 could sample plots 3 and 4. On survey day 2, they could switch: observer 1 could sample plots 3 and 4 and observer 2 could sample plots 1 and 2. If it is necessary for more than one observer to conduct a survey within a single reference plot at the same time, please designate one person as the **lead observer** and note that on the field form. The lead observer should survey the wetland independently and unimpeded by the additional observer(s) who should trail behind and be sure not to influence the survey of the lead observer. The total number of turtles, as well as the number observed by the lead observer should be recorded on the VRA field form.

Protocol for Processing Individual Turtles

When a Spotted Turtle is captured (either during trapping or visual surveys), the turtle observation field form should be completed, and the following protocols are recommended. Turtles should not be removed from the site, should be restrained for as little time as possible, and should be returned to their capture location. NOTE: each time a turtle is recaptured in a season, please complete another individual form for the turtle, even though one has already been completed. It is not necessary to re-measure the turtle (the turtle ID, date, and location fields, at a minimum, should be completed).

Morphometrics: Record shell dimensions in mm. At a minimum, record SCLmin (straight carapace length) and SPLmin (straight plastron length). Optionally, also record: PW @ H-P seam (plastron width at humeral/pectoral seam), CW @ V3/4 (carapace width at the 2nd and 3rd vertebral line), and SH (shell height at the 2nd and 3rd vertebral line). Dial calipers 6"/500 mm are recommended.
Weight: Record animal mass in g (Pesola scale 250 g or 500 g).
Age and Plastral Wear: Assess the animal's age if new growth is visible along the medial seams and the plastral scutes are only lightly worn. Otherwise, report the minimum number of annuli visible and whether the plastral scutes are "not worn" (≤10% wear), "partly worn" (<50%), "mostly worn" (50%-90%) or "worn" (>90%).
Individual marking: Turtles should be individually notched as directed by state coordinators. Secondary recognition is recommended using photographs, injuries, deformities, PIT tags, etc. Only trained researchers should insert PIT tags. When marking animals, we recommend the use of a numeric notching code (e.g., Cagle 1939 or Ernst et al. 1974) where numbers are added to obtain

a single ID number, rather than a code that refers to scute locations only (e.g., R2 R3), because scute code data are harder to manage than numeric data.
Photographs: Photograph carapace and plastron with animal ID visible in photo (or sorted/ tagged post-capture). If possible, photograph lateral head shot and limbs/tail, as well as obvious injuries or deformities.
Injuries and general health: Note missing or injured limbs, tail, eyes, etc., as well as the presence of skin or upper respiratory tract infection or lethargic condition.
Scute morphology and other deformities: Note any major scute or other deformities, including less than or more than 12 marginals on either or both sides.
Tissue collection for genetic analysis: With approval from state coordinators, trained researchers may consider collecting blood or tissue samples for genetic sampling. See tissue collection protocol.

Required Equipment

The following equipment is required to complete the protocol: field forms, writing implements, GPS for recording trap locations and visual survey points/tracks, flagging for marking traps, calipers (~6 in), Pesola scale ≥500 g, extra slim taper triangular file (for marking turtles), camera or cell phone for photographing turtles, air and water thermometers, and 20 traps/site operated at a time with associated stakes, ties, and bait. Additional optional equipment may also be necessary including waders, polarized sunglasses, binoculars, disinfecting equipment, and/or blood sampling equipment. Because researchers currently have a range of available equipment, specifications are flexible. Any traps >0.2 m in diameter with < 3 cm mesh are acceptable, though we recommend that all five traps within a single reference plot be the same type of trap. These variations will be incorporated as a covariate in the modeling process. To help standardize future equipment purchases, we recommend medium or large sized ProMar, collapsible minnow traps (Model TR502 or TR503, 12" diameter by 24" or 36" length with 5" dual openings. https://promarnets.com/product/deep-water-crawfish-crab-nets/ (Figure 2). [Note: we do NOT recommend the smaller, square, red ProMar model]). This model trap has been used successfully by researchers throughout the species range for over a decade. Alternatively, we recommend hard-sided crab traps like those used in Georgia and Florida (Chandler et al. 2017). Hard-sided traps are particularly useful in areas where raccoons or other predators are an issue. Alternatively, to prevent raccoon depredation, researchers have had success retrofitting ProMar traps with chicken wire or hardware cloth on the outside (Figure 3).

Figure 2. Promar TR502 (left) and modified crab trap from Chandler et al. (2017).

Figure 3. ProMar retrofitted with chicken wire to prevent raccoon depredation (J. Meck)

Trap identification: Assign unique ID to each trap and label trap in the field and on the corresponding field form.
Trap location/operation: Record trap ID, lat/long (decimal degrees), and functional period (mm/dd-mm/dd), and complete appropriate field form upon trap placement.
Bait: Sardines in oil (Beach Cliff or other brand).
Re-bait frequency: 24 hr (puncture can, do not open entirely, or use part of a can in a container that allows the oil to escape, but not the fish).
Trap check frequency: 24 hr with more frequent checks as required by agencies/partners or flood conditions.

General protocols to reduce likelihood of disease transfer

Several states and research teams within the region already have a standard decontamination procedure in place to prevent the spread of disease, and teams should follow their local practices and procedures. For those teams without a decontamination protocol, we suggest several precautionary measures to prevent the spread of disease. A 3% bleach solution may be used to disinfect traps and clothing between sites. After bathing or spraying tools and clothing in the bleach solution, items should be rinsed with clean water. Captured turtles from different sites and those displaying signs of illness should be held separately during processing, and equipment should be sterilized between turtles. Calipers should be swabbed with alcohol, files can be burned, and notches should be dabbed with Betadyne. Latex gloves for handling turtles are an additional precautionary suggestion. The Northeast Partners for Amphibian and Reptile Conservation (NEPARC) Disinfection Protocol contains additional recommendations (http://northeastparc.org/disinfection-protocol).

Data Entry

For any of the protocols, enter your data onto the standardized field forms available at http://northeastturtles.org while in the field. Upon returning to the office, electronically enter data as soon as possible into the formatted Excel Worksheet also available on the website.

Data Analysis

Data will be managed at the regional level by C-SWG partners, including American Turtle Observatory, Smithsonian Conservation Biology Institute, and Mid-Atlantic Center for Herpetology and Conservation. Rapid Assessments will be analyzed in a mixture modeling framework (Royle 2004) using the unmarked (Fiske and Chandler 2011) package in R (R Core Team 2021). Demographic Assessment sites will be analyzed in a capture mark recapture framework using the Rcapture (Baillargeon and Rivest 2007) package or spatially explicit capture recapture techniques (Royle et al. 2011) using the secr package (Efford 2017) in R.

Plot Size and Trap Night Justification

To determine appropriate plot sizes and trap distances for sampling design, we reviewed the literature to evaluate known movement distances for Spotted Turtle. Ideally, each reference plot would be independent at the scale of an entire sampling event (an active season) and therefore be larger than, but the same order of magnitude as, a Spotted Turtle home range, and large enough to encompass many Spotted Turtle home ranges. A 200-m radius plot is equivalent to a 12.6 ha plot, slightly larger than three times the size of the average minimum convex polygon (MCP) measured via radio-telemetry by Milam and Melvin (2001), between the average size of male and female

MCPs observed by Litzgus and Mosseau in South Carolina (2004*b*), and large enough to encompass the home ranges of multiple individuals. Thirteen turtles tracked for a year in Florida by J. Mays (unpublished data) fell within a 13ha area. It should be noted that some individuals move much farther, however; Milam and Melvin (2001) tracked an individual 1125m in a year, J. Mays has tracked males in Florida that moved over 1200 m straight line over the course of a year, but both are within the order of magnitude of the reference plots we suggest.

The four combined reference plots would be equivalent to about 50 ha. In the expert poll, respondents stated that known Spotted Turtle populations from Maine to Florida range in size from 0.7 ha to over 100 ha. The proposed four-reference plot arrangement allows for a broad configuration of sites to be sampled and encompasses all of the size classes provided by experts. Traps themselves should be far enough away to be independent at the scale of a single trap night, so that animals are not observed in different traps on the same day, but close enough that animals might be recaptured in adjacent traps on different nights. The recommended 30 m separation distance represents the average daily movement distance observed by Litzgus and Mosseau (2004*b*) by females during the spring season in South Carolina (Table 1). In addition, 30 m is consistent with the trap separation distance most often used by experts from Maine to Florida.

Table 1. Movement and home range distances of Spotted Turtles from previous studies.

Author	Location	Sample Size, method	Mean home range area (ha)	Home range length (m)	Mean Daily Movement (m/day)
Beaudry et al. 2007, 2008	ME	40 radio-telemetry	9.3 ha (95% FKE, Range: 0.3 - 64.0) or 7.9 ha (MCP, Range: 0.4 - 40.0)		102 (SD = 0, range: 18– 251) using thread trailing
Milam and Melvin 2001.	MA	26 (10M, 16F), radio-telemetry	3.5 ha (Range: 0.2-53.1)	313 (Range: 115-1125)	
Buchanan et al. 2017.	RI	12 radio-telemetry	1.95 ha (MCP) Range: 0.59-4.07ha		
Litzgus and Mosseau, 2004b	SC	31 (9M, 22F), radio-telemetry	Male: MCP = 5.15±1.13, 95% Kernel = 4.67±0.61; Gravid Female: MCP = 19.06±6.75, 95% Kernel = 10.35±2.29		Male (n=7-9): spring =21.77±0.39, nesting = 10.7±0.22, late summer = 10.41±0.28, fall = 10.34±0.3, winter = 7.13±0.28; Gravid Female (n=16-20): spring = 26.96±0.36, nesting = 19.89±0.17, late summer = 33.44±0.45, fall = 8.04±0.11, winter = 2.33±0.07
Mays, unpub. data	FL	29 (11M, 18F)	MCP = 2.3 (Range: 0.1-20.6); 95% Kernel = 4.5		

(Range: 0.4-40.3)

Similarly, to estimate the required number of trap nights, we reviewed recent literature and compiled information from experts across the region. Across studies in Rhode Island, Massachusetts, Maryland and Florida, traps yielded an average of 0.3 Spotted Turtle captures/trap night (Table 2). Region-wide in 2018, 8020 trap nights across 57 sites yielded 714 Spotted Turtle captures, for an average region-wide capture rate of 0.089 turtles/TN or 11.2 TN for 1 Spotted Turtle. Though this was substantially lower than our estimate based on previous data, it included many exploratory sites rather than primarily known populations that were included in Table 2. Excluding sites where no turtles were captured in 2018, trap success averaged 0.13 turtles/TN in 2018.

As expected, capture rates in 2018 were highly variable across sites, and ranged from 0 turtles/TN (for 26 sites, including one site that was trapped as many as 320 TN) to 0.675 turtles/TN. Once covariates (such as weather and time of year) are included in the model, some of this variation may be explained. There will always be errors of omission with any protocol, but with a few exceptions, results from 2018 suggest that the 80 TN design seems sufficient to identify very high-density sites. To assess whether the 240 TN DA protocol was sufficient, we used the package Rcapture (Baillargeon and Rivest 2007) in R (R Core Team 2021) to calculate rough population estimates for DA sites trapped in 2018. Of the 12 sites trapped using the DA framework for which data were available, four sites yielded estimates with relatively tight confidence intervals (95% CI range was 16 turtles or less), 4 sites yielded estimates with confidence intervals 50 to 100 turtles wide, and four sites yielded estimates with 95% confidence intervals greater than 174 turtles wide (including two sites with no recaptures at all) (Figure 4). This suggests that although the DA protocol works well for some sites, some sites with a lower density or lower recapture rate may require additional trap nights or higher trap density. Based on these results from the 2018, it was determined that higher densities of traps may be necessary for better demographic estimates at some sites, and the Working Group added the *Demographic, High Density Trapping* protocol described above.

Table 2. Capture rates and population estimates with known trapping effort from previous studies

Authors	Location	Total TN	Individuals	Captures	Turtles /TN	Population Estimate	Estimate Standard Error
Buchanan, pers. comm.	Rhode Island	40	21	24	0.6		
Willey, Jones, Milam, unpublished data, 2014	Massachusetts Total	216	23	58	0.27		
Willey, Jones, Milam, unpublished data, 2014	MA Site 1- Hampshire Co.	109	13			11.3	SE=0.6
Willey, Jones, Milam, unpublished data, 2014	MA Site 2- Franklin Co.	107	10			21.2	SE=7.8
Mays, in Chandler et al. 2017	Florida	698		32	0.05		
Chandler et al. 2017	Georgia	866		146	0.17		
Howell, unpublished data	Maryland				0.79		
Liebgold, unpublished data	Maryland				0.02		
Approximate average (assuming equal trap effort)					**0.32**		

Literature Cited

Baillargeon, S., and L. Rivest 2012. Rcapture: Loglinear Models for Capture-Recapture Experiments. R package version 1.3.1. http://CRAN.R-project.org/package=Rcapture.

Beaudry, F., P. deMaynadier., and M.L. Hunter. 2007. A Study of Movement, Habitat Selection, and Population Viability of Spotted and Blanding's Turtles in Southern Maine. Unpublished final report.

Beaudry, F., P. deMaynadier., and M.L. Hunter, Jr. 2008. Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. Biological Conservation 141 (10): 2550-2563.

Buchanan, S.W., B. Buffum, N.E. Karraker. 2017. Responses of a Spotted Turtle (*Clemmys guttata*) Population to Creation of Early-successional Habitat. Herpetological Conservation and Biology 12(3):688–700.

Cagle, F.R. 1939. A system of marking turtles for future recognition. Copeia 1939: 170–173.

Chandler, H.C., D.J. Stevenson, J.D. Mays, B. S. Stegenga, W. H. Vaigneur, and M. D. Moore. 2017. A new trap design for catching small Emydid and Kinosternid turtles. Herpetological Review 48(2): 323-327.

Efford, M. G. 2017. secr: Spatially explicit capture-recapture models. R package version 3.1.3. https://CRAN.R-project.org/package=secr

Ernst, C.H., M.F. Hershey, and R.W. Barbour. 1974. A new coding system for hard-shelled turtles. Journal of the Kentucky Academy of Science 35:27–28.

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. URL http://www.jstatsoft.org/v43/i10/

Litzgus, J.D., and T. A. Mousseau. 2004. Home Range and Seasonal Activity of Southern Spotted Turtles (Clemmys guttata): Implications for Management. Copeia 2004(4): 804-817.

Milam, J.C., and S.M. Melvin. 2001. Density, habitat use, movements, and conservation of Spotted Turtles (*Clemmys guttata*) in Massachusetts. Journal of Herpetology 35:418–427.

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Royle, J.A. 2004. *N*-mixture models for estimating population size from spatially replicated counts. Biometrics 60:108-115.

Royle, J.A., and J.D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology 84(3):777-790.

Royle, J.A., M. Kéry, and J. Guélat. 2011. Spatial capture-recapture models for search-encounter data. Methods in Ecology and Evolution 2(6):602-611.

Spotted Turtle Monitoring Protocol Overview

PLANNING PHASE

□ Select and delineate a wetland complex

- Select sites with a known population OR potentially suiTable habitat
- Use leaf-off aerial imagery
- Confirm permission to access property

□ Place up to four 200-m radius reference plots centered on suiTable Spotted Turtle habitat

- Reference plot centroids should be 400–800 m apart

□ Conduct a reconnaissance visit

SURVEY PHASE

□ Option 1: Trap-based assessments (rapid or long-term)

- Set five traps (recommended: ProMar TR-502 24"x12" collapsible turtle traps [optional: with chicken wire retrofit] or FL/GA crab traps) per sampling plot (20 total per site)
- Complete the trap set-up field form
- Place traps:
  - Ideally 30 m apart (no less than 15 m)
  - In high potential use wetlands and microhabitat
  - Such that there is adequate headspace for turtles to breathe
- Affix traps at two locations (at least) to ensure they cannot be moved by animals
- Bait traps with ½ can of sardines in oil and rebait every 24 hours (note if a different bait is used on the field form)
- Check traps every 24 hour
  - Complete a trap check field form whenever traps are checked
  - Complete an individual turtle form for each Spotted Turtle captured

□ Trap-based Rapid Assessment (TRA)

- A single trap-run (using the above methodology) consisting of four nights

□ Demographic Assessment (DA)

- Three, 4 night trap-runs, for a total of 12 trap-nights (using the above methodology).
- Nights 5-12 could use higher trap densities under the DA, High Density Trapping protocol.

□ Option 2: Visual Rapid Assessment (VRA)

- On foot, actively search each reference plot for 20 minutes (80 minutes per visit to a site)
  - Small seasonal pools should be searched in their entirety before moving to the next wetland in the reference plot

- The beginning and ending points of surveys for long, linear wetland features (ditches or canals) should be recorded
    - In larger wetlands, a meandering transect survey should be conducted and GPS track should be logged.
- A VRA is complete when three surveys are conducted at a site within a four-week window
- Complete a VRA field form for each visit to a site
- Each visit should be conducted by a single observer
- Attempt to rotate observers for consecutive visits to a site to reduce bias
- Record GPS tracks as well as start and end coordinates

Appendix 6-A.

Environmental covariates considered within analyses of abundance and age structure. See Appendix 6-D for which variables were included for specific analyses.

Class	Metric	Cover Type
Wetland	Area (ha)	All wetland types (excluding estuarine and marine)
Wetland	Area (ha)	Shallow palustrine wetlands (emergent, shrub, forested)
Wetland	Area (ha)	Forested wetlands
Wetland	Area (ha)	Shrub wetlands
Wetland	Area (ha)	Emergent wetlands
Wetland	Shannon's Diversity	All wetlands
Wetland	Shannon's Diversity	Shallow palustrine wetlands (emergent, shrub, forested)
Wetland	Shannon's Diversity	Wetland-Regime
Wetland	Proportion of wetlands	Ephemeral wetlands
Land Cover	Mean cell value	Imperviousness
Land Cover	Proportion	Roads
Land Cover	Proportion	Hay/pasture
Land Cover	Proportion	Cultivated crops
Landscape Structure	Aggregation Index	Wetland

Appendix 6-B.

Definitions of wetland and hydroperiod types from the National Wetland Inventory.

Category	Type	Definition
Wetland	Forested	The Class Forested Wetland is characterized by woody vegetation that is 6 m tall or taller. All water regimes are included except subtidal.
Wetland	Shrub	The Class Scrub-Shrub Wetland includes areas dominated by woody vegetation less than 6 m (20 feet) tall. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions. All water regimes except subtidal are included.
Wetland	Emergent	The Emergent Wetland Class is characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants. All water regimes are included except subtidal and irregularly exposed.
Wetland	Pond/Lake	UB: The Class Unconsolidated Bottom includes all wetland and deepwater habitats with at least 25% cover of particles smaller than stones, and a vegetative cover less than 30%. Water regimes are restricted to subtidal, permanently flooded, intermittently exposed, and semipermanently flooded. AB: The Class Aquatic Bed includes wetlands and deepwater habitats dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years. Water regimes include subtidal, irregularly exposed, regularly flooded, permanently flooded, intermittently exposed, semipermanently flooded, and seasonally flooded. L: The Lacustrine System (Figure 5) includes wetlands and deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30% areal coverage; and (3) total area exceeds 8 ha (20 acres). Similar wetland and deepwater habitats totaling less than 8 ha are also included in the Lacustrine System if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin exceeds 2 m (6.6 feet) at low water. Lacustrine waters may be tidal or nontidal, but ocean derived salinity is always less than 0.5 ‰.
Wetland	Estuarine	The Estuarine System consists of deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. The salinity may be periodically increased above that of the open ocean by evaporation. Along some low-energy coastlines there is appreciable dilution of sea water. Offshore areas with typical estuarine plants and animals, such as red mangroves (*Rhizophora mangle*) and eastern oysters (*Crassostrea virginica*), are also included in the Estuarine System.[3]

Category	Type	Definition
Wetland	Riverine	The Riverine System includes all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts in excess of 0.5 ‰. A channel is "an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water" (Langbein and Iseri 1960:5).
Hydrologica l Regime	Permanently Flooded	Water covers the land surface throughout the year in all years. Vegetation is composed of obligate hydrophytes.
Hydrologica l Regime	Temporarily Flooded	Surface water is present throughout the year except in years of extreme drought.
Hydrologica l Regime	Semipermanentl y Flooded	Surface water persists throughout the growing season in most years. When surface water is absent, the water Table is usually at or very near the land surface.
Hydrologica l Regime	Seasonally Flooded	Surface water is present for extended periods especially early in the growing season but is absent by the end of the season in most years. When surface water is absent, the water Table is often near the land surface.
Hydrologica l Regime	Semipermanentl y Flooded	The substrate is saturated to the surface for extended periods during the growing season, but surface water is seldom present.
Hydrologica l Regime	Temporarily Flooded	Surface water is present for brief periods during the growing season, but the water Table usually lies well below the soil surface for most of the season. Plants that grow both in uplands and wetlands are characteristic of the temporarily flooded regime.
Hydrologica l Regime	Intermittently Flooded	The substrate is usually exposed, but surface water is present for variable periods without detectable seasonal periodicity. Weeks, months, or even years may intervene between periods of inundation. The dominant plant communities under this regime may change as soil moisture conditions change. Some areas exhibiting this regime do not fall within our definition of wetland because they do not have hydric soils or support hydrophytes.
Hydrologica l Regime	Artificially Flooded	The amount and duration of flooding is controlled by means of pumps or siphons in combination with dikes or dams. The vegetation growing on these areas cannot be considered a reliable indicator of water regime. Examples of artificially flooded wetlands are some agricultural lands managed under a rice-soybean rotation, and wildlife management areas where forests, crops, or pioneer plants may be flooded or dewatered to attract wetland wildlife. Neither wetlands within or resulting from leakage from man-made impoundments, nor irrigated pasture lands supplied by diversion ditches or artesian wells, are included under this modifier.

Appendix 6-C.

Summary of information related to individual species models, including total number of sites, error distribution (nb = negative binomial, zip = zero-inflated Poisson), and the maximum number of detection, wetland, and land cover covariates considered for each species.

Species	Detections	Sites with occurrence	Sites sampled	Proportion sites occupied	Max. detection covariates	Max. wetland covariates	Max. land cover covariates	Error distribution
Spotted Turtle	1087	188	522	0.36	4	3	3	Negative binomial
Spotted Turtle juvenile	78	58	58	1	NA	2	2	Binomial
Loggerhead musk turtle	1				NA	NA	NA	NA

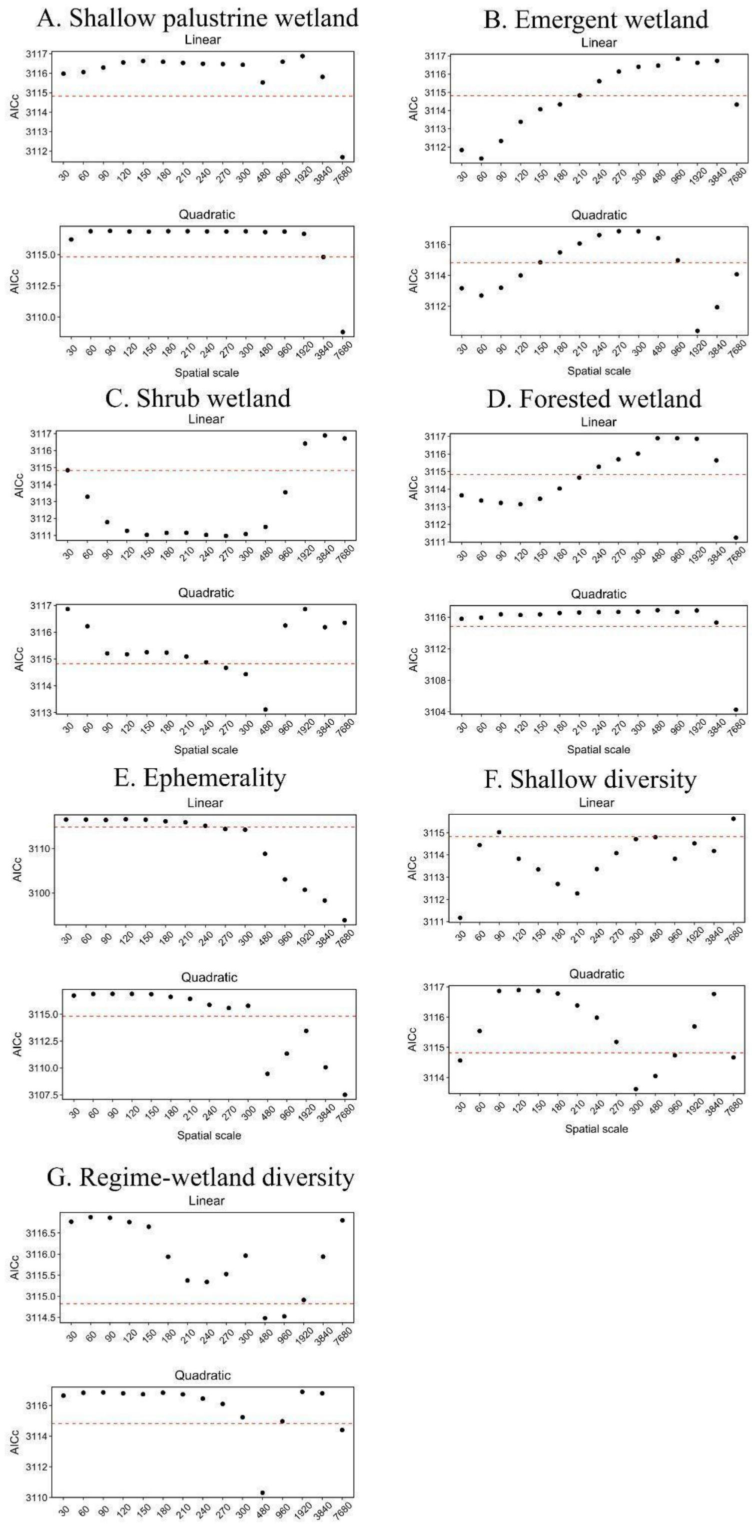
Appendix 6-D.

Environmental covariates considered for each species. Cells containing "x" indicate variables that were included in respective species analyses.

Species	Wetland Amount						Wetland Ephemerality		Wetland Diversity			Land Cover			
	All wetlands	Shallow palustrine	Emergent	Shrub	Forest	Pond	All wetlands	Shallow palustrine	All wetlands	Shallow palustrine	Wetland-Regime	Road density	Impervious	Cultivated crops	Hay
Spotted Turtle		x	x	x	x			x		x	x	x	x	x	x
Spotted Turtle (juvenile)		x	x	x	x			x		x	x	x	x	x	

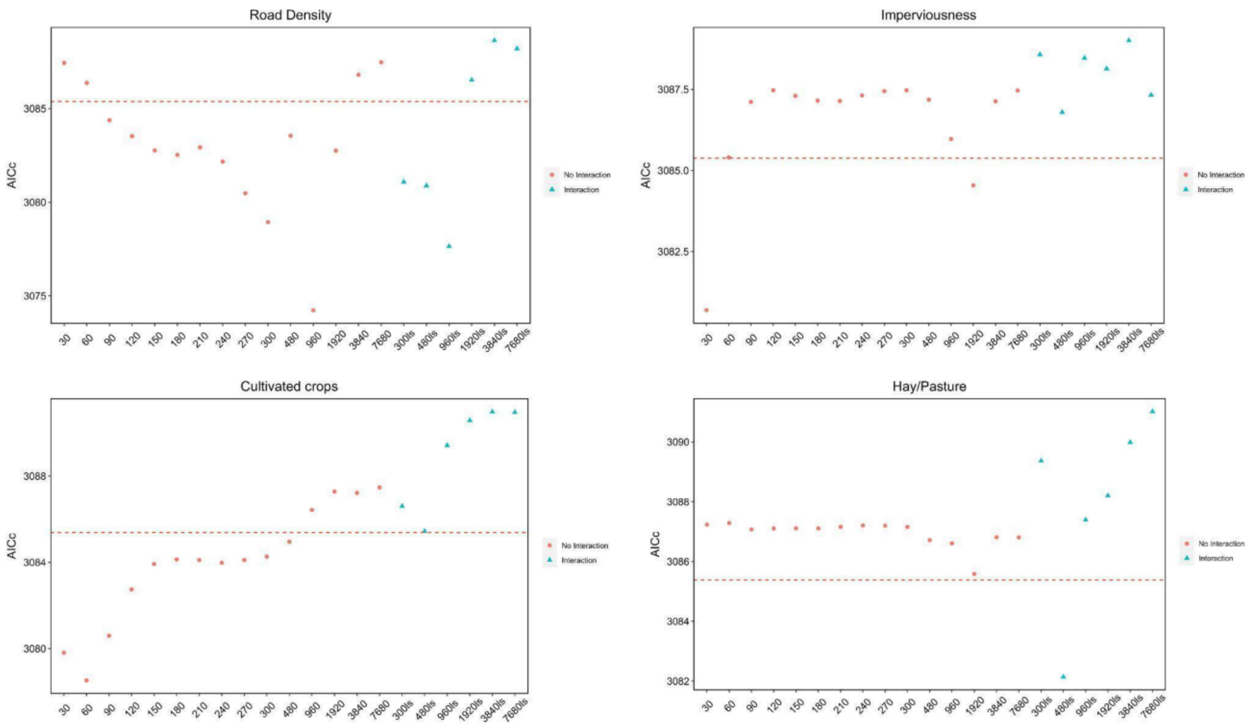
Appendix 6-E.

AICc values for each scale considered for each wetland variable. Red dashed line indicates the null model with no site variables.



Appendix 6-F.

AICc values for each scale considered for each land cover variable. Red dashed line indicates the null model with no land cover variables. Colors and shapes indicate whether the model includes an interaction with wetland aggregation.



Appendix 7-A.

Population estimates for sampled Spotted Turtle sites with greater than 5 captures and 2 recaptures.

Site	Region	Model	Captures	Abundance	Stderr	Upper	Lower	InfoFit
MA_A	Northeast	M0	48	154.9	50.3	253.488	56.312	Ok
MA_B	Northeast	M0	30	156.9	83.9	321.344	-7.544	Ok
MA_C	Northeast	M0	16	26.6	6.6	39.536	13.664	Ok
MA_D	Northeast	M0	71	105.3	10.8	126.468	84.132	Ok
MA_E	Northeast	M0	37	110.2	38	184.68	35.72	Ok
MA_F	Northeast	M0	33	148.8	68.1	282.276	15.324	Ok
MA_G	Northeast	M0	34	95	32.3	158.308	31.692	Ok
MA_H	Northeast	M0	12	40	24.8	88.608	-8.608	Ok
MA_I	Northeast	M0	28	30.4	1.9	34.124	26.676	Ok
MA_J	Northeast	M0	8	34.7	12.5	59.2	10.2	Ok
MA_K	Northeast	M0	13	20.2	5.2	30.392	10.008	Ok
ME_A	Northeast	M0	23	43.9	12.2	67.812	19.988	Ok
ME_B	Northeast	M0	8	13.3	6	25.06	1.54	OK
ME_C	Northeast	M0	19	90.9	58.9	206.344	-24.544	Ok
ME_D	Northeast	M0	97	152.9	14.9	182.104	123.696	Ok
ME_E	Northeast	M0	16	60.5	37.8	134.588	-13.588	Ok
ME_F	Northeast	M0	16	60.5	37.8	134.588	-13.588	Ok
NH_A	Northeast	M0	24	37.6	7.4	52.104	23.096	Ok
NH_B	Northeast	M0	12	23.9	9.3	42.128	5.672	Ok
NH_C	Northeast	M0	24	101.9	52.7	205.192	-1.392	Ok
NH_D	Northeast	M0	31	49.2	8.7	66.252	32.148	Ok
RI_A	Northeast	M0	12	36.4	22	79.52	-6.72	Ok
RI_B	Northeast	M0	18	33.5	10.7	54.472	12.528	Ok
DE_A	Mid-Atlantic	M0	33	63.6	14.1	91.236	35.964	Ok
DE_B	Mid-Atlantic	M0	135	193.3	13.6	219.956	166.644	Ok
DE_C	Mid-Atlantic	M0	42	60.3	7.6	75.196	45.404	Ok
DE_D	Mid-Atlantic	M0	11	59.4	55.1	167.396	-48.596	Ok
DE_E	Mid-Atlantic	M0	38	48.1	4.8	57.508	38.692	Ok
DE_F	Mid-Atlantic	M0	30	70.4	20.3	110.188	30.612	Ok
DE_G	Mid-Atlantic	M0	6	6.8	1.2	9.152	4.448	Ok
DE_H	Mid-Atlantic	M0	39	125.7	41.6	207.236	44.164	Ok
DE_I	Mid-Atlantic	M0	54	259.9	97.6	451.196	68.604	Ok
DE_J	Mid-Atlantic	M0	40	95.6	23.8	142.248	48.952	Ok
DE_K	Mid-Atlantic	M0	33	68.5	16.3	100.448	36.552	Ok
DE_M	Mid-Atlantic	M0	18	20.3	1.9	24.024	16.576	Ok
MD_A	Mid-Atlantic	M0	214	308.6	17.4	342.704	274.496	Ok
MD_B	Mid-Atlantic	M0	38	157.9	64	283.34	32.46	Ok

Site	Region	Model	Captures	Abundance	Stderr	Upper	Lower	InfoFit
MD_C	Mid-Atlantic	M0	15	29.7	10.2	49.692	9.708	Ok
MD_D	Mid-Atlantic	M0	16	32.9	11.5	55.44	10.36	Ok
MD_E	Mid-Atlantic	M0	16	18.7	2.2	23.012	14.388	Ok
MD_F	Mid-Atlantic	M0	28	61.6	16.7	94.332	28.868	Ok
NJ_A	Mid-Atlantic	M0	20	43.7	14.3	71.728	15.672	Ok
NJ_B	Mid-Atlantic	M0	31	161.2	85.9	329.564	-7.164	Ok
NJ_C	Mid-Atlantic	M0	12	69.6	64.9	196.804	-57.604	Ok
NY_A	Mid-Atlantic	M0	38	121.1	40	199.5	42.7	Ok
NY_B	Mid-Atlantic	M0	5	6.4	2	10.32	2.48	Ok
NY_C	Mid-Atlantic	M0	36	109.1	35.7	179.072	39.128	Ok
NY_D	Mid-Atlantic	M0	32	59.6	13.7	86.452	32.748	Ok
NY_E	Mid-Atlantic	M0	14	25.8	9.2	43.832	7.768	Ok
NY_F	Mid-Atlantic	M0	5	8.7	4.4	17.324	0.076	Ok
PA_A	Mid-Atlantic	M0	37	81.4	21.1	122.756	40.044	Ok
PA_B	Mid-Atlantic	M0	6	19.3	16.8	52.228	-13.628	Ok
PA_C	Mid-Atlantic	M0	41	79.5	15.5	109.88	49.12	Ok
PA_D	Mid-Atlantic	M0	15	45.2	22.6	89.496	0.904	Ok
PA_E	Mid-Atlantic	M0	5	9.1	4.9	18.704	-0.504	Ok
PA_F	Mid-Atlantic	M0	7	25.1	22.2	68.612	-18.412	Ok
FL_A	South	M0	5	7.2	2.7	12.492	1.908	Ok
FL_B	South	M0	32	87.9	28.2	143.172	32.628	Ok
GA_A	South	M0	6	7.8	2.2	12.112	3.488	Ok
GA_B	South	M0	46	47	1.1	49.156	44.844	Ok
GA_C	South	M0	12	19.8	5.8	31.168	8.432	Ok
NC_A	South	M0	87	414	141	690.36	137.64	Ok
NC_B	South	M0	9	22.3	12.9	47.584	-2.984	Ok
NC_C	South	M0	17	33.4	11.2	55.352	11.448	Ok
VA_A	South	M0	86	174.7	24.8	223.308	126.092	Ok
VA_B	South	M0	39	76.3	15.8	107.268	45.332	Ok
VA_C	South	M0	5	8	3.7	15.252	0.748	Ok
VA_D	South	M0	12	17.5	4.5	26.32	8.68	Ok
VA_E	South	M0	18	56.7	28.2	111.972	1.428	Ok
VA_F	South	M0	18	24.6	4.4	33.224	15.976	Ok
VA_G	South	M0	14	47.7	29.4	105.324	-9.924	Ok
VA_H	South	M0	71	88.3	6	100.06	76.54	Ok
VA_I	South	M0	16	43.6	21	84.76	2.44	Ok
VA_J	South	M0	36	212.8	114.7	437.612	-12.012	Ok
VA_K	South	M0	21	44	13.2	69.872	18.128	Ok
VT_A	South	M0	15	33.4	13.3	59.468	7.332	Ok
WV_A	South	M0	20	38.8	11.2	60.752	16.848	Ok

Site	Region	Model	Captures	Abundance	Stderr	Upper	Lower	InfoFit
WV_B	South	M0	12	17.9	4.5	26.72	9.08	Ok
WV_C	South	M0	70	382.4	134.8	646.608	118.192	Ok
WV_D	South	M0	30	48.8	9	66.44	31.16	Ok

Appendix 11-A.

Diagram of the multi-stage process used to identify final models of Spotted Turtle sex ratio.