Species Status Assessment Report

for the

Spotted Turtle

(*Clemmys guttata*)

Version 1.1

Photo credit: Mike Jones, MA Division of Fisheries and Wildlife

June 2025

U.S. Fish and Wildlife Service

Northeast Region

Chesapeake Bay Field Office

Annapolis, Maryland

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Summary of Version Updates

The changes from version 1.0 (January 2024) to version 1.1 (June 2025) did not change the SSA analysis for spotted turtle. The changes included minor edits to Literature Cited.

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EXECUTIVE SUMMARY

The spotted turtle (*Clemmys guttata*) is a small aquatic turtle found throughout the eastern coast of the United States and the Great Lakes region, from Maine south along the Atlantic Coastal Plain and Piedmont to Florida, and west to northeastern Illinois and Michigan. Although broadly distributed, the species is fairly uncommon in much of its range. Populations at the northern and southern extremes appear small, and the spotted turtle occurs in very low densities in Florida. Spotted turtles, like other turtle species, have high egg and juvenile mortality, iteroparity (repeated reproductive events over the lifespan), low adult mortality, and a long life, typically living at least 30 years, potentially up to 65 to 110 years old. Generation time has not been calculated for the spotted turtle but is likely 20 to 30 years. Because spotted turtles are long-lived with high egg and hatchling mortality, population persistence relies on high adult and subadult survivorship, and increases in adult mortality can have large, lasting negative impacts on populations.

Generally, spotted turtles require wetland habitats with clear, clean water, soft substrate, and aquatic vegetation adjacent to accessible upland habitats. Throughout the year, spotted turtles can exploit a wide variety of mostly freshwater, shallow, wetland habitats, including sphagnum swamps, wooded swamps, small ephemeral and permanent pools, bogs, fens, wet meadows, cattail marshes, sedge meadows, small woodland streams, and drainage ditches, as well as the edges of bays and ponds and tidally influenced brackish streams. They often use different wetlands in different parts of the year, moving to new areas depending on the season and local conditions. Their activity patterns are somewhat temperature dependent, and spotted turtles have temperature dependent sex determination, with more females produced at higher temperatures. Although individual clutch sizes decrease from north to south, total annual reproductive output may be consistent across the range due to southern populations being able to lay multiple clutches due to the extended active period. Alternatively, southern populations may be capable of exceeding reproductive output of the northern populations. Spotted turtles are omnivorous scavengers and have been observed eating both plant and animal foods.

Habitat loss, degradation, and fragmentation, both historical and ongoing, are the largest and most often cited threats to the viability of the spotted turtle. Habitat impacts can occur primarily through human land use changes and climate change. Land use changes, specifically additional development, can increase the likelihood of some of the other biggest threats to the species; for instance, more roads increase the risk of road mortality and additional access to sites increases the risk of illegal collection. Human developments can often attract and subsidize mammalian mesopredators, which can increase predation of nests, juveniles, and adults. Climate change is leading to sea level rise which is affecting coastal habitats, and changing rainfall patterns and increasing temperatures can have impacts ranging from causing habitat loss, causing individual mortality, helping the spread of invasives, altering the active period of turtles, shifting sex ratios to more females, and reducing individual fitness.

To determine the current condition for the spotted turtle, we first reviewed the literature to determine what factors would be important to consider in our analysis. We worked with species experts across the range to develop a table that summarizes relevant information for each state

within each defined analysis unit. We selected the EPA Level III (L3) Ecoregions as analysis units for this species, further divided by state boundaries. Because spotted turtles exist in wetlands that vary in their type, vegetation, and other ecological factors based on location, we propose that habitats likely are more similar within rather than among ecoregions, and habitats within an ecoregion can likely be managed in similar ways. We requested summary information from each state for each of these analysis units within the range of the spotted turtle; this provided a common spatial reference that could be used by all states. Responses for habitat availability, population density within occupied habitats and connectivity of those occupied habitats, and the population trajectory for each analysis unit were standardized using a dropdown in the excel spreadsheet, meaning that only a certain range of responses was allowed. We first assigned each analysis unit an "abundance score" based on the habitat availability and population density in those habitats, as shown in Table A.

Table A. Abundance scores based on the population density in and connectivity of occupied habitats and the habitat availability and connectivity of habitat available within each analysis unit as reported by each state. Abundance scores are weighted towards the population density.

	Habitat available				
Population density in occupied habitats:	**Abundant, widespread, connected**	**Abundant and widespread but isolated**	**Somewhat abundant and widespread with some connectivity**	**Uncommon with some connectivity**	**Uncommon, isolated**
Individuals abundant and widespread with habitat connectivity	High	High	High	High	Moderate
Individuals abundant and widespread but highly fragmented	High	High	High	Moderate	Moderate
Individuals somewhat abundant and widespread with some habitat connectivity	High	Moderate	Moderate	Moderate	Low
Individuals uncommon with restricted occurrence and some connectivity	Moderate	Moderate	Low	Low	Low
Individuals uncommon with restricted occurrence and highly fragmented	Low	Low	Low	Low	Low

We then considered the population trajectory response alongside this abundance score to assign a resiliency rating for each analysis unit (Table B). Note that a "stable" trajectory can shift the abundance score up to a higher resiliency rating, and only those analysis units that were given a "decreasing" trajectory are given a "low" resiliency rating. Because spotted turtles have persisted in areas away from the coastal plain where habitat is naturally uncommon and isolated, we hypothesize even sparse populations can be moderately resilient.

Table B. Resiliency rating assignments, based on the Abundance Score (Table A) and population trajectory, as reported by each state. Resiliency ratings should be considered relative and a proxy for true population resiliency.

	Trajectory			
Abundance Score	**Stable**	**Varies**	**Unknown**	**Decreasing**
High	High	High	High	Moderate
Moderate	High	Moderate	Moderate	Low
Low	Moderate	Moderate	Moderate	Low

We received data from all 21 states within the range of the spotted turtle, within 7 L2 Ecoregions and 23 L3 ecoregions, for a total of 79 analysis units. Range wide, 11 percent of the total range is classified as having a high resiliency rating, while 17 percent of the range has a low resiliency rating; the remaining 72 percent has a moderate resiliency rating. Most of the analysis units with a high resiliency rating are located along the Atlantic coast, mostly within the Southeast USA Coastal Plain Level II ecoregion (Figure A). Areas that have a low resiliency rating are spread throughout the range of the species.

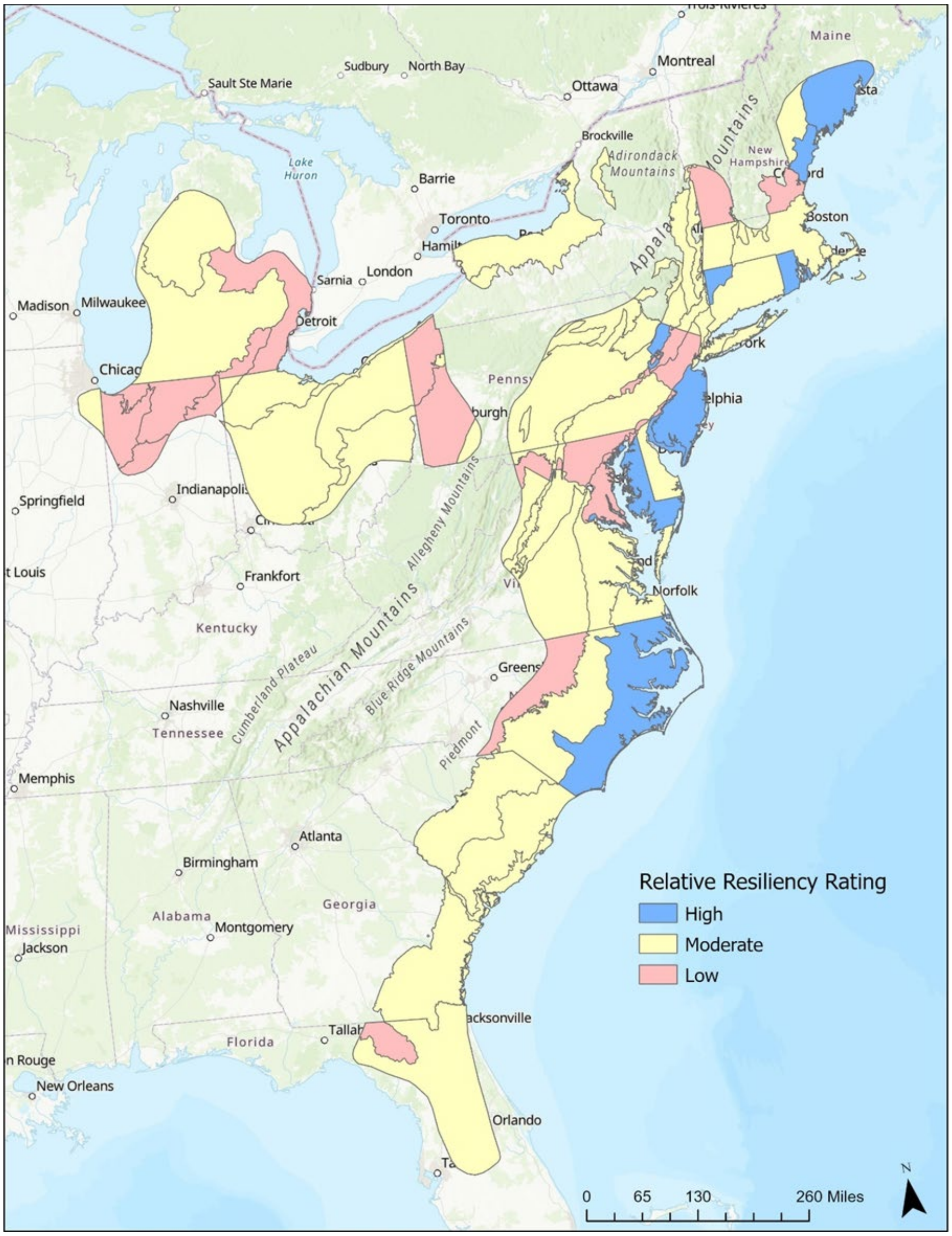

Figure A. Resiliency rating of each analysis unit following methodologies above.

The factors most likely to affect viability in the future are habitat loss and fragmentation; the loss of adults primarily due to collection, road mortality, and predation; and increasing temperatures and changing rainfall patterns, which will result in habitat loss but are also likely to have an impact of unknown magnitude on spotted turtle behaviors, activity patterns, nesting success, and physiology. Each of these factors can be attributed directly or indirectly to one or both of two main sources: land use change and climate change. We assessed the future condition of the spotted turtle using models that predict future land use change and climate change. We chose to examine future condition at two timesteps, 2050 and 2100, roughly 25 and 75 years into the future. At each timestep, we forecast changes in resiliency under two climate scenarios: a Moderate impact scenario, using lower climate trajectories and impacts and models corresponding to this trajectory, and a High impact scenario which follows a higher trajectory for climate effects, using the corresponding models. To calculate the magnitude of future impacts to spotted turtles, we used two metrics: (1) the amount of existing wetlands that are lost in the future due to either general land use change or sea level rise, and (2) the percent of each analysis unit that will become developed in the future. For each of the first two metrics, we assigned an impact value depending on their magnitude of change (Table C), and summed these impact values, weighing the direct loss of existing wetlands double that of additional development in the analysis unit. We additionally considered likely changes in temperature and precipitation, specifically the change in the number of days per year with an ambient temperature over 38 °C (100 °F), which is near the thermal max of the species (41.7 °C (107 °F)) and is likely to affect the timing of behaviors and spotted turtle physiology, as well as contribute to wetland drying, which is currently a concern in the southeast region. Models of future precipitation are less certain but generally predict more annual rainfall, especially in the northern portions of the range, although the timing and amounts is unknown; therefore, impacts on spotted turtles are also uncertain.

Table C. Relative impact values for various amounts of existing habitat that is lost within an analysis unit, as well as percent of the analysis unit that becomes developed, binned by none, low, moderate, and high.

Sum Percent Habitat Lost /New Development	Impact	Impact Value
≤5	None	0
>5 to 20	Low	1
>20 to 40	Moderate	2
>40	High	3

For each combination of this summed habitat impact value and the current resiliency in the analysis unit, we assigned a risk of extirpation to each analysis unit (Table D). This risk should be interpreted as the risk that individual populations within the analysis unit will become extirpated.

Table D. Classification of future condition given an analysis unit's current resiliency rating and the future impact magnitude (combination of habitat loss and development).

<table>
<tr><th rowspan="2">Habitat Impacts</th><th colspan="3">Current Relative Resiliency Rating</th></tr>
<tr><th>High</th><th>Moderate</th><th>Low</th></tr>
<tr><td>0</td><td rowspan="4">Likely viable</td><td rowspan="2">Likely viable</td><td rowspan="2">Moderate risk of extirpation</td></tr>
<tr><td>1</td></tr>
<tr><td>2</td><td rowspan="2">Moderate risk of extirpation</td><td rowspan="8">Higher risk of extirpation</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td><td rowspan="2">Moderate risk of extirpation</td><td rowspan="6">Higher risk of extirpation</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td><td rowspan="4">Higher risk of extirpation</td></tr>
<tr><td>7</td></tr>
<tr><td>8</td></tr>
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</table>

By 2050, analysis units where populations are likely to remain viable account for 57 percent of the range (Table E) and are mostly in the interior of the range, inland from the coast and the midwest region, as well as within the northernmost edge of the range in New England (Figure B). The highest risks of population extirpations are generally within the southernmost areas in the range and along the eastern portions of Pennsylvania. This remains true by 2100 under a moderate scenario, but under a high scenario by 2100, most of the coastal regions and much of the midwest analysis units have a high risk of population extirpations (Figure B). The proportion of the range that remains likely viable under a high scenario in 2100 is 30 percent (Table E).

Table E. The percentage of the spotted turtle range that is expected to likely remain viable or have a lower or higher risk of extirpation in the future under both scenarios at both timesteps.

	Percent of Range			
Future Condition	**Mod 2050**	**High 2050**	**Mod 2100**	**High 2100**
Likely viable	57.2	56.7	53.4	29.6
Lower risk of extirpation	28.5	26.7	31.3	23.8
Higher risk of extirpation	14.3	16.6	15.4	46.6

Because the specific impacts of climate change on spotted turtles are uncertain and will vary, we are unable to make specific predictions of climate impacts. However, we assume that the likelihood or intensity of potential effects to the spotted turtle due to climate change will increase: (1) over time, such that climate effects at the 2100 timestep will be more likely to impact spotted turtles than the 2050 timestep, and (2) with the higher impact climate scenario, such that climate effects under the high scenario will be more likely to impact the spotted turtle than the moderate scenario.

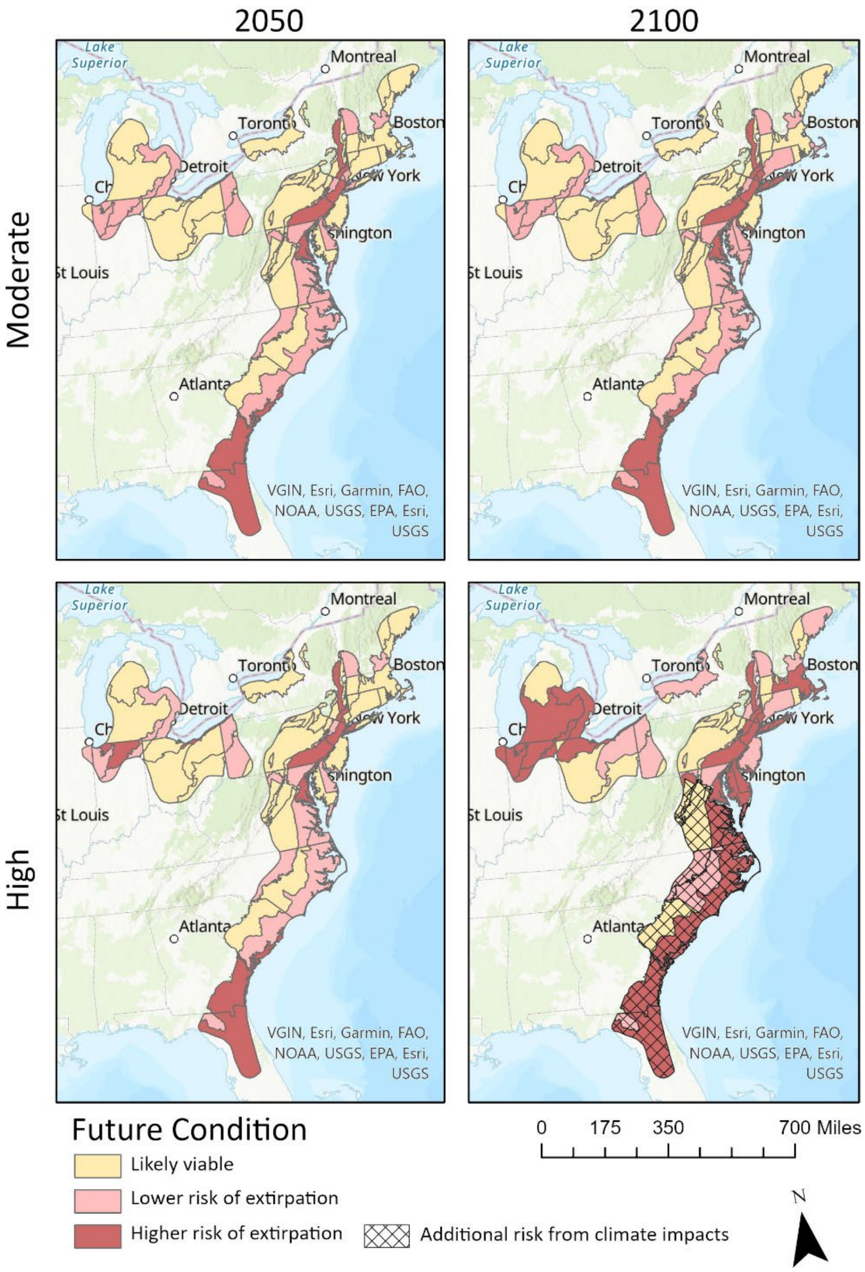

Figure B. Projected future condition of the spotted turtle. Risk of extirpation refers to localized or widespread population extirpations within each analysis unit. While we cannot accurately quantify the additional risk of climate change, the best available information suggests that climate change will increase the risk of extirpation in the southeast region.

Further, we make some generalizations about the impacts of climate change by region (northeast, from Maine to Maryland; midwest, western New York and Pennsylvania west to Michigan; and southeast, from Virginia to Florida), given the specific predictions and existing models of future temperature and rainfall and how they differ across regions. While impacts from climate change are expected to impact spotted turtles to some extent across the range at both timesteps and in both scenarios, the best available information indicates that climate change impacts in the midwest and northeast are not great enough to have a major impact on viability across those regions. Models of temperature increases indicate that the number of days over 38 °C (100 °F) stay below 30 throughout the range until 2100, increasing to above 30 days on average only under a high climate scenario and only in the southeast region, with states from Virginia to Florida seeing on average between 30 and 80 days of these temperatures annually. While we do not know the full impact of these heat days, the southeast region will have additional significant impacts from climate change by 2100 under a high scenario, which will elevate the risk of local or potentially widespread population extirpations. Thus, in 2100 under a high scenario, the southeast will have the added risk of climate impacts (Figure B).

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1 INTRODUCTION

The spotted turtle (*Clemmys guttata*) was included in a petition from the Center for Biological Diversity, dated July 11, 2012, requesting that 53 species of reptiles and amphibians be listed as an endangered or threatened with designated critical habitat under the Endangered Species Act (ESA). A substantial 90-day finding published on September 18, 2015, concluded that listing may be warranted (80 FR 37578). Spotted turtles are identified as Species of Greatest Conservation Need (SGCN) in all 21 states in their range and are considered Endangered by the International Union for Conservation of Nature (IUCN) (van Dijk 2011, entire; Willey et al. 2022, p. 12).

The Species Status Assessment (SSA) framework (USFWS 2016, entire) is intended to support an in-depth review of the species' biology and threats to its persistence, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA to be easily updated as new information becomes available, to support functions of the Endangered Species Act from Candidate Assessment to Listing to Consultations to Recovery, and to support decision-making at all levels (Smith et al. 2018, entire). This SSA report version for the spotted turtle is intended to provide the biological support for a status review and for potential future actions under the ESA as needed. Importantly, the SSA does not result in a decision by us (the U.S. Fish and Wildlife Service (USFWS)) on whether this species should be proposed for classification under the Act. Rather, this SSA provides a review of the best available information strictly related to the biological status of the species. We will make the classification decision after reviewing this document and all relevant laws, regulations, and policies, and the results of any proposed decision will be announced in the Federal Register, with appropriate opportunities for public input.

For the purpose of this assessment, we generally define viability as the ability of the spotted turtle to sustain populations in its natural range over time. Using the SSA framework (Figure 1), we consider what the species needs to maintain viability (Wolf et al. 2015, entire). To assess viability, we use the conservation biology principles of resiliency, redundancy, and representation (Shaffer and Stein 2000, pp. 308–311). To sustain populations over time, a species must have the capacity to withstand:

(1) environmental and demographic stochasticity and disturbances (Resiliency),

(2) catastrophes (Redundancy), and

(3) novel changes in its biological and physical environment (Representation).

A species with a high degree of resiliency, redundancy, and representation (the 3Rs) is better able to adapt to novel changes and to tolerate environmental stochasticity and catastrophes. In general, species viability will increase with increases in resiliency, redundancy, and representation (Smith et al. 2018, p. 306).

- Resiliency is the ability of a species to withstand environmental stochasticity or normal, year-to-year variations in environmental conditions such as temperature and rainfall; periodic disturbances within the normal range of variation such as fire, floods, and storms; and demographic stochasticity or normal variation in demographic rates such as mortality and fecundity (Redford et al. 2011, p. 40). Therefore, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions. We can best gauge resiliency by evaluating population level characteristics such as demography, genetic health, and connectivity and by evaluating habitat factors such as quantity, quality, configuration, and heterogeneity. Also, for species prone to spatial synchrony, or regionally correlated fluctuations among populations, distance between populations and degree of spatial heterogeneity, or diversity of habitat types and microclimates, are also important considerations.

- Redundancy is the ability of a species to withstand catastrophes. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaptation is unlikely (Mangel and Tier 1993, p. 1083). We can best gauge redundancy by analyzing the number and distribution of populations relative to the scale of anticipated species-relevant catastrophic events. The analysis entails assessing the cumulative risk of catastrophes occurring over time. Redundancy can be analyzed at a population or regional scale, or for narrow-ranged species, at the species level.

- Representation is the ability of a species to adapt to both near-term and long-term changes in its physical and biological environments. This ability to adapt to new environments, referred to as adaptive capacity, is essential for viability, as species need to continually adapt to their continuously changing environments (Nicotra et al. 2015, p. 1269). Species adapt to novel changes in their environment by either moving to new, suitable environments or by altering their physical or behavioral traits, also called phenotypes, to match the new environmental conditions through either plasticity or genetic change (Beever et al. 2016, p. 132; Nicotra et al. 2015, p. 1270). Genetic change occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Crandall et al. 2000, pp. 290–291; Sgro et al. 2011, p. 327; Zackay 2007, p. 1). We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In assessing the breadth of variation, it is important to consider both larger-scale variation such as morphological, behavioral, or life history differences that might exist across the range, and smaller-scale variation such as measures of interpopulation genetic diversity. When assessing the dispersal ability of a species, it is important to evaluate the ability and likelihood of the species to track suitable habitat and climate over time. Lastly, to evaluate the evolutionary processes that contribute to and maintain adaptive capacity, it is important to assess 1) natural levels and patterns of gene flow, 2) degree of ecological diversity occupied, and 3) effective population size. In our SSAs, we assess all three facets to the best of our ability based on available data.

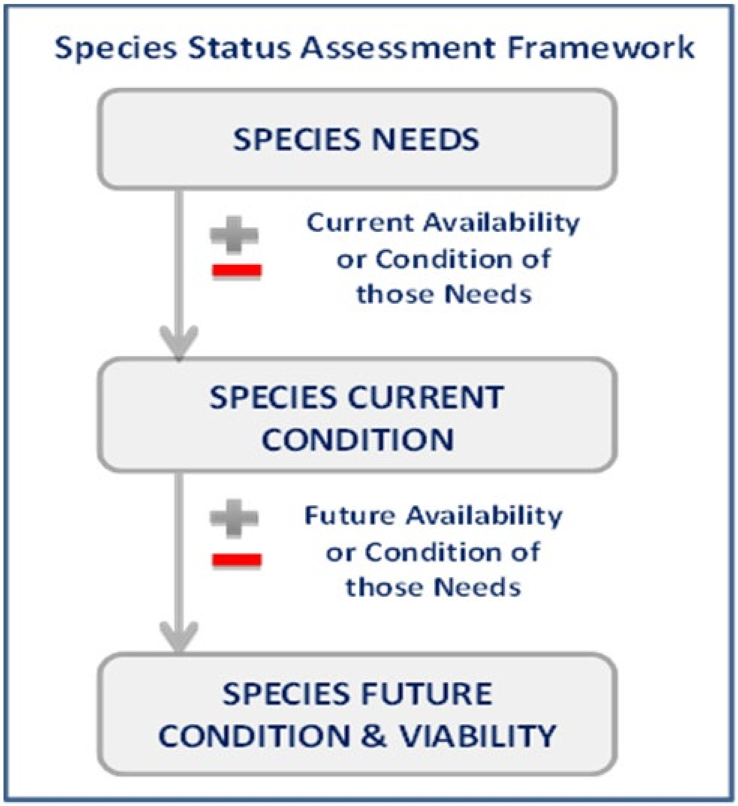

Figure 1. Species Status Assessment Framework.

To evaluate the biological status of the spotted turtle, we assessed a range of conditions to allow us to consider the species' current and future resiliency, redundancy, and representation. This SSA report provides a thorough assessment of biology and natural history and assesses risks, threats, and limiting factors in the context of determining the viability of the species. We assess future resiliency at two future timesteps, 2050 and 2100, which will also indicate trends in habitat changes over time.

The format for this SSA includes species biology (Section 2), species needs (Section 3), influences on viability (Section 4), current condition (Section 5), and future condition (Section 6). This document is a compilation of the best available scientific and commercial information and a description of past, present, and plausible future population and habitat conditions for the spotted turtle.

2 SPECIES BIOLOGY

2.1 Species Description and Taxonomy

The spotted turtle is a small aquatic turtle (3.5 to 4.5 inches (in)), 9 to 11.5 centimeter (cm)) with a black carapace with yellow spots. Hatchlings usually have one spot per large scute on the shell, but adult spotting patterns are variable. Spotted turtle have flattened carapace shells, orange or yellow coloration on their head, neck, and forelegs, and males have longer tails than females (Ernst and Lovich 2009, pp. 212). Females are generally brighter in coloration than males; the reasons for this are unknown but are potentially related to female competition, a reversal of sex roles typical in turtles (Liebgold et al. 2023, p. 9).

While males and females do not show size dimorphism in terms of carapace length, females have heavier body mass, longer plastrons, and higher shells, likely due to the lack of concavity of their shells (Gray 2004, p. 21; Litzgus and Brooks 1998b, p. 773; Litzgus and Mousseau 2004a, p. 391; Rowe et al. 2012, p. 443).

Spotted turtles are the only extant species currently in the genus *Clemmys* (Bickham et al. 1996, entire; Holman and Fritz 2001 *In* NatureServe 2023; Crother et al. 2003, p. 203). The currently accepted classification is:

Order Testudines
Suborder Cryptodira
Superfamily Testudinoidea
Family Emydidae
Subfamily Emydinae
Genus *Clemmys*
Species *Clemmys guttata* (Schneider, 1792)

Genetics

At the local scale in populations of spotted turtles on the Delmarva peninsula, genetic structure indicated high relatedness within 18 km (11 mi) but less than expected relatedness at distances greater than 18 km, indicating that spotted turtles rarely disperse beyond 18 km (Liebgold et al. 2022, p. 8). There is evidence that, although the spotted turtle experiences habitat fragmentation and loss, levels of heterozygosity within demographically and genetically isolated populations are relatively high and comparable with other species of turtles (Davy and Murphy 2014, pp. 150–154; Buchanan et al. 2019a, pp. 38–39; Scolville 2019, pp. 10–11). However, when comparing individuals from a small wetland with those from a nearby large wetland with greater numbers of individuals, the individuals in the small wetland had reduced genetic diversity (Parker and Whiteman 1993, p. 844), which may indicate that a reduction in genetic diversity is occurring but due to long generation times may be difficult to detect in most populations (McCluskey et al. 2016, p. 75).

A recent study of spotted turtles across Ontario, Canada revealed a hierarchical arrangement of population clusters. Populations also exhibited isolation by distance consistent with ongoing genetic connectivity limited by spatial dispersal capability (Davy and Murphy 2014, p. 155). This study sampled 253 turtles (approximately 10 percent of the current estimated Canadian population size) from 13 sites (52 percent of the currently known extant sites). Despite genetic isolation and small size, each subpopulation maintained high heterozygosity (0.510 to 0.743) and showed no evidence of inbreeding or subpopulation decline (within-site allelic richness ranged from 3.18 to 4.49), and no subpopulations were fixed for alleles at any loci (Davy 2013, pp. 38–39; Davy and Murphy 2014, pp. 155–160). Subpopulations are biogeographically isolated (Davy 2013, pp. 36–37; Davy and Murphy 2014, p. 157) and spread across different eco-regions (Great Lakes/St. Lawrence Faunal Province and Carolinian Faunal Province); however, there is no evidence of local adaptation or significant differences in subpopulation trends or factors affecting them (COSEWIC 2014, p. 7). Spotted turtle reproductive behaviors, such as aggregation breeding and possibly non-random mate choice ('inbreeding avoidance'), may be influencing genetic diversity within subpopulations more than small subpopulation size and genetic isolation (Davy 2013, p. 37; Davy and Murphy 2014, p. 157).

In a recent genetic study conducted in Indiana and Ohio, Scolville (2019, p. 30) observed heterozygosity that was similar across all sites (n=6) (0.061 – 0.781, mean of 0.678, n=100 individuals) and comparable to observations by Davy and Murphy (2014, pp. 38 – 39). The study also identified three distinct genetic clusters and evidence of population bottlenecks in two populations (Scolville 2019, p. 31). Buchanan et al. (2019a, pp. 10–11) 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. However, 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, p. 844; Anthonysamy et al. 2017, p. 142) and snapping turtles (*Chelydra serpentina*; Anthonysamy et al. 2017, p. 142). Because gene flow was lower in spotted turtles compared to painted turtles and snapping turtles, the authors concluded that 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, p. 844; Davy 2013, p. 70; Anthonysamy et al. 2017, p. 142). 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, p. 37; Davy and Murphy 2013, p. 154 (no significant heterozygosity excess detected); Buchanan et al. 2019, p. 8 (F_{IS} 0.039, CI=0.0094-0.0628); Scolville 2019, p. 24, 31 (F_{is} 0.0935–0.1330)).

A genetics study occurred as part of a Competitive State Wildlife Grant (CSWG) effort to develop a Conservation Plan for the species in the eastern U.S. (see Section 4.5, below; funding was provided by a Northeast Regional Conservation Needs grant and Service funding) (Dyer and Whitehurst 2023, entire). Standing structure and diversity within and among populations was examined using Single Nucleotide Polymorphisms from 913 individuals, 78 locales, and 16 states in the eastern U.S. Samples from the Midwest and Canada will also be analyzed and compared to the eastern U.S. samples later in 2023 (pers. comm, R. Dyer, 2023). A more extensive analysis of genetic samples from Michigan and Ohio will also be completed in early 2024 (Cross 2023, pers. comm). The amount and spatial distribution of genetic diversity and structure was similar to work conducted by Buchanan et al. (2019a, entire; F_{st} 0.014); Davy and Murphy (2014, p. 154; F_{ST} 0.038) and Scolville (2019, p. 28; F_{st} 0.029 to 0.076), reporting low standing structure (i.e., few genetic differences across study area, Eastern U.S.), weak association of inter-locale differentiation due to spatial isolation (isolation by distance), and weak partitioning across populations due to models of historical admixture. The species appears to have lower genetic structure than almost all other North American turtles including Blanding's turtle (*Emydoidea blandingii*) (Mockford et al. 2007, entire), both subspecies of sliders (*Trachemys scripta* var. *scripta* and var. *elegans*) (Parham et al. 2020, entire), western pond turtle (*Actinemys marmorata*), and wood turtle (*Glyptemys insculpta*). The only species with lower standing structure is the diamondback terrapin (*Malaclemys terrapin*) (Dyer and Whitehurst 2023, p. 20). Low standing genetic structure may be present due to several mechanisms. It is possible that the genetic effective population size of the existing population is large enough to offset the diversifying strength of genetic drift. It is also possible that isolation by distance, which suggests some limitation in dispersal potential, is not pervasive enough to result in spatial partitioning across the landscape. There is a reduction in individual heterozygosity with increasing latitude but no evidence of discrete genetic units throughout the whole eastern part of the range (Dyer and Whitehurst 2023, p. 20). This is most likely a residual signal from large scale post-Pleistocene range expansion (Dyer and Whitehurst 2023, pp. 1–21).

In summary, there is no evidence of discrete genetic units or unique alleles present in the eastern part of the species' range. Comparisons with the Midwest portion of the range will not be conducted until late 2023 or early 2024 to determine if there is divergence between the eastern U.S. and the Midwest and among the Midwestern states. A recent study conducted in Ohio and Indiana did show three discrete genetic units among six sites. Genetic diversity was comparable to other species of turtles in Ontario, Rhode Island, Ohio, and Indiana but lower than painted turtles and snapping turtles in the Great Lakes region which may result in a higher risk for genetic drift. Additionally, spotted turtles across the Great Lakes and East Coast regions are at a high risk of inbreeding when population sizes are small.

2.2 Distribution

The spotted turtle is found throughout the eastern coast of the United States and the Great Lakes region, from Maine south along the Atlantic Coastal Plain and Piedmont to Florida, and west to northeastern Illinois and Michigan (Ernst and Lovich 2009, p. 213) (Figure 2). They occur in Connecticut, Delaware, District of Columbia, Florida, Georgia, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Vermont, Virginia, and West Virginia (USFWS 2015, p. 35758). The species is also found in the southern Canadian province of Ontario.

The species inhabits seven EPA Level II (L2) Ecoregions: the Mixed Wood Plains, which is an area of glaciated, rolling to level terrain with mixed landcover; the Central USA Plains, characterized by areas of glaciated, flat-to-gently rolling plains; the Southeastern USA Plains, comprising the inner coastal plains, Piedmont areas, and interior low plateaus; the Appalachian

Forests, which are unglaciated forested mountains and upland plateaus; the Southeast USA Coastal Plains, which are low-lying and characterized by a mosaic of wetlands, forests, and water; the Mixed Wood Shield, characterized by land that is mostly glaciated, with broad, smooth landforms; and the Atlantic Highlands, comprised of forested upland areas that were formerly glaciated (Figure 2) (Sleeter et al. 2014, pp. 18–22). By area and L2 Ecoregion, the Southeast USA Coastal Plains and Mixed Wood Plains each account for 24 percent of the total range; altogether the percent of the range that occurs along the coastal areas (these two L2 Ecoregions, plus Southeastern USA Plains) accounts for 69 percent of the total range. Mixed Wood Shield makes up three percent of the range (Table 1).

Table 1. EPA Level II Ecoregions that fall within the range of the spotted turtle, and the percentage of the total range comprised of each. Note that not all areas are occupied within range extent.

L2 Ecoregion		Percent total range
8.1	Mixed Wood Plains	24%
8.2	Central USA Plains	12%
8.3	Southeastern USA Plains	21%
8.4	Appalachian Forests	11%
8.5	Southeast USA Coastal Plains	24%
5.2	Mixed Wood Shield	3%
5.3	Atlantic Highlands	5%

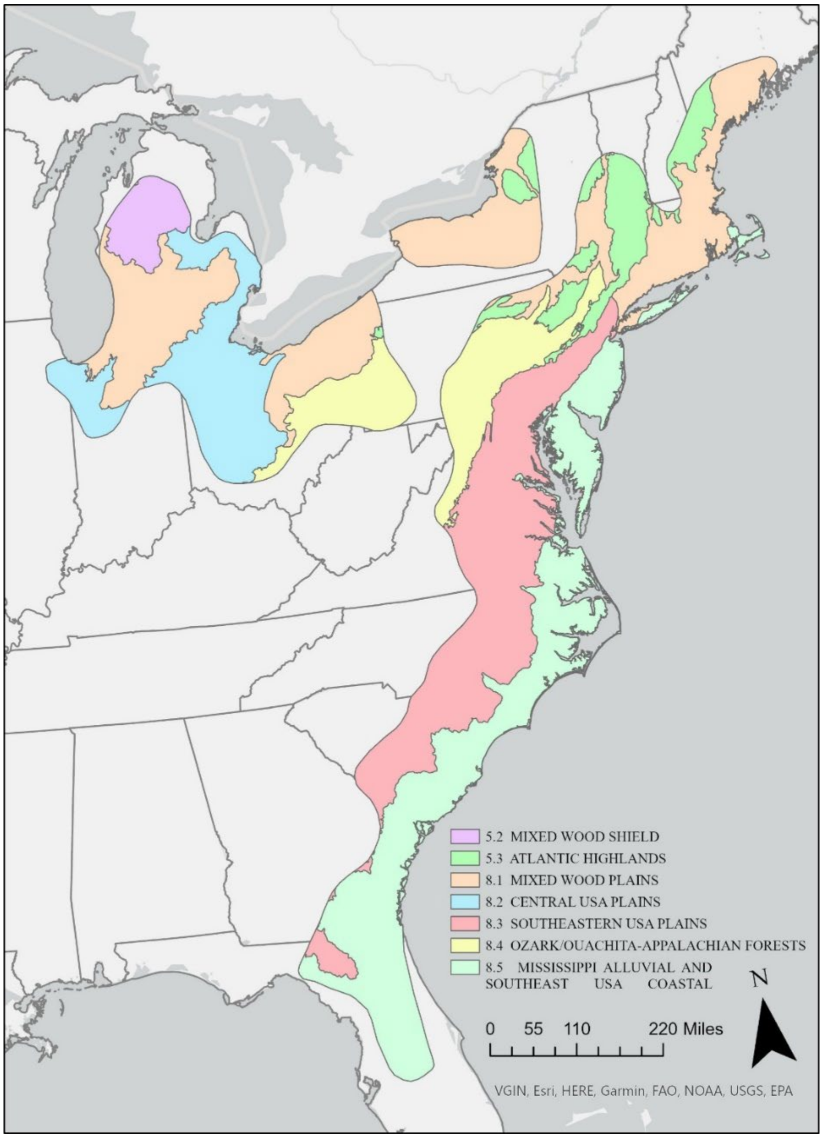

Figure 2. Approximate range of the spotted turtle within the U.S. and corresponding L2 Ecoregions (noting that the species range in the Canadian Province of Ontario is not represented). Boundary represents approximate extent of detections; not all areas are occupied.

Although broadly distributed, the species has always had smaller population sizes outside of coastal areas along the eastern U.S. Northern and southern extremes also appear small, and the spotted turtle occurs in very low densities in Florida (Ernst and Lovich 2009, p. 221; Meylan 2006, p. 231). The species no longer occurs in southern Québec (Ernst and Lovich 2009, p. 213).

Through a recent CSWG, spotted turtle habitat was delineated from 11,957 spotted turtle occurrence records throughout the eastern U.S. (not including the Midwest and from fewer locations in the southern U.S.) (see Figure 2). The majority of these occurrence records (605) were older than 1990 (Willey et al. 2022, pp. 3–4). Sites representing potential habitat were created by buffering occurrences by 500 meters (m) (1,640 feet (ft)) and including adjacent suitable wetlands (freshwater emergent and forest/shrub that intersected but extended outside of the 500m occurrence buffer) which were buffered by 200 m (656.17 ft) to include uplands. This process resulted in 2,351 sites delineated totaling 769,080 hectares (ha) (2,969.43 square (sq) miles (mi)) of habitat, the average of which is 327.5 ha (1.26 sq mi) and contains 5.2 records. The greatest density and number (61 percent) of sites occur along the Coastal Plain from New England to Virginia, and generally, fewer sites occur further inland and at higher elevations. The low ranges of the Appalachian Mountains are hypothesized to create a partial barrier between the eastern and western portions of the species range (again, not including the midwestern portion) (Willey et al. 2022, pp. 3–4).

Species Protection Status

Spotted turtles are classified globally as endangered by the IUCN and endangered in Canada. They are listed as endangered in four states (IL, OH, IN, VT) and threatened in three states (ME, NH, MI) and are designated as a Regional Species of Greatest Conservation Need in all 21 states in which they occur (Willey et al. 2022, p. 3).

Due to its popularity in the pet trade, in 2013, the species was added to Appendix II of the Convention on International Trade in Endangered Species (CITES), which includes species that may become threatened with extinction if their trade is not strictly regulated (CITES 2013, pp. 1–13; Willey et al. 2022, pp. 26–27). The U.S. Lacey Act (18 USC 42–43; 16 USC 3371–3378) also prohibits interstate transportation of spotted turtles collected in violation of the law and then sold.

NatureServe provided a rank of G5 (secure) in 2016 (NatureServe Explorer 2023, entire).

Regarding habitat protection, the Clean Water Act section 404 established a program to regulate the discharge of dredged and fill material into waters of the United States. Permits to fill wetlands or streams are issued by the U.S. Army Corps of Engineers, and mitigation is required to offset impacts above minimal levels. Habitat used by the spotted turtle consists primarily of non-tidal and ephemeral wetland types. A recent Supreme Court ruling (U.S. Supreme Court, Sackett vs. Environmental Protection Agency et al. 2023, entire) found that "waters of the United States" consists of streams, oceans, rivers, lakes, and wetlands contiguous with those waterbodies. Therefore, this decision will likely result in less protection of wetlands used by the spotted turtle but the full extent of how the regulation will play out is unknown at this time. Individual states and local jurisdictions may also have regulations that protect non-tidal wetlands; however, the amount of protection varies across the species' range.

2.3 Life History

Much of the known life history of the spotted turtle comes from studies in three main locations: Ontario, at the northern end of their range; Pennsylvania, near the middle latitudes of their range;

and South Carolina, near the southern end of their range. Thus, within this SSA, differences among these latitudes are pointed out, and we note where data comes from when data are only available for part of the range.

Lifespan and Demographics

Spotted turtles, like other turtle species, have high egg and juvenile mortality, iteroparity (repeated reproductive events over the lifespan), low adult mortality, and a long life. Turtle subpopulations can sustain years of low juvenile recruitment if reproducing adults are not lost to death or overharvesting (Stearns 1976, p. 26). Sensitivity analyses of life table parameters indicate that spotted turtle subpopulation viability is highly dependent upon adult survivorship (Litzgus 2006, p. 285). These life history attributes make turtle subpopulations susceptible to decline and extirpation when as little as one to three percent of reproducing adults are lost from subpopulations (Doroff and Keith 1990, p. 397; Brooks et al. 1991 *In* COSEWIC 2014, p. 23; Congdon et al. 1993, p. 832; Congdon et al. 1994, p. 404; Gibbs and Shriver 2002, p. 1649; Enneson and Litzgus 2008, p. 1,565–1,566).

Spotted turtles have some of the highest survivorship and longevity estimates of any animal species (Litzgus 2006, p. 281). Individuals typically live at least 30 years, potentially up to 65 to 110 years old (Figure 3) (Litzgus 2006, p. 281; van Dijk 2011, p. 2). Females are significantly longer-lived than males; females can live to a maximum estimated around 110 years, while males reach a maximum around 65 years (Litzgus 2006, p. 281). Models based on over 24 years of mark-recapture data from an Ontario, Canada Georgian Bay subpopulation produced the following minimal annual survivorship estimates for spotted turtles: 96.5 percent for adult females, 94.2 percent for adult males (Litzgus 2006, p. 284; Enneson and Litzgus 2008, p. 1563), and 82 percent for juveniles (Enneson and Litzgus 2008, p. 1563); annual adult recruitment (i.e., percent of juveniles that turn into adults each year) was low at 2.2 percent (Enneson and Litzgus 2008, p. 1563). In North Carolina on a large, forested property from 2012 to 2013, spotted turtles exhibited high annual survival unrelated to sex or time, and female annual survival (0.978) was approximately 6 percent greater than males (0.921) (O'Bryan 2014, p. 10). In Illinois during 2015 and 2016, a mark–recapture study of two populations, along with historical mark–recapture data from 1988 to 2010, determined female age-specific survival and fecundity rates (Feng et al. 2019a, entire). Survival increased significantly with age, and age-specific reproductive output and fecundity were greater than 1.0 (Feng et al. 2019a, p. 650). However, both populations exhibited net reproductive rates below replacement levels, and one population had a negative growth rate (Feng et al. 2019a, p. 650). Both populations exhibited a strong adult bias (76.5 to 90.6 percent) (Feng et al. 2019a, p. 650). Also in the North Carolina population, monthly survival rates in a heavily managed pine plantation were high with an annual population growth rate greater than 1 (O'Bryan 2014, p. ii).

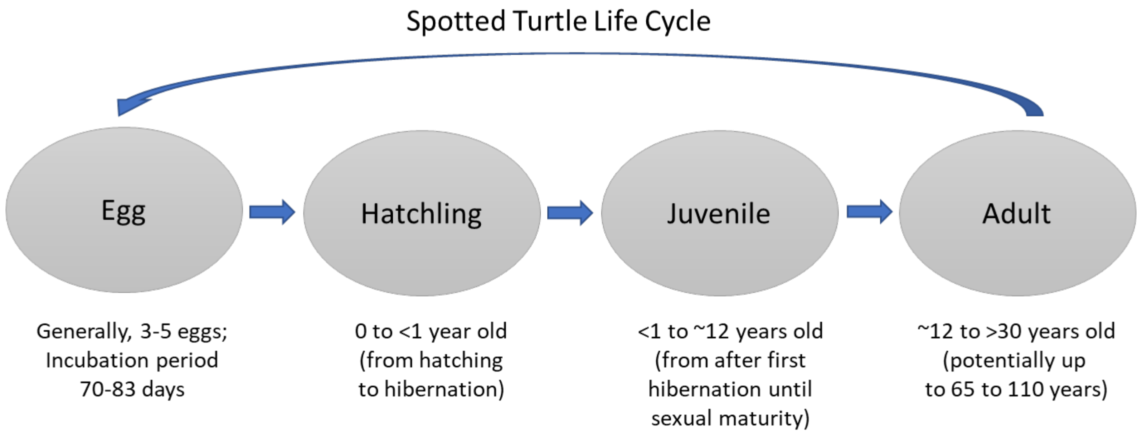

Figure 3. Life cycle stages of a spotted turtle.

The adult sex ratio for spotted turtles does not typically differ from 1:1 (Ernst 1976, p. 28; Feng et al. 2019a, p. 648; Graham 1995, p. 209; Gray 2004, p. 26; Litzgus and Mousseau 2004a, p. 391). Spotted turtles reach sexual maturity at a moderate age (7 to 13 years in males, 7 to 15 years in females) compared to other wetland turtle species, but they have comparably high adult survivorship and low reproductive output (Feng et al. 2019b, p. 12; van Dijk 2011, p. 2). As such, populations are typically adult biased (e.g., 77 to 91 percent in Illinois) (Feng et al. 2019a, p. 648). However, several spotted turtle populations in Maryland and Delaware have negatively skewed size distributions; while adults are present, few old, larger individuals are found (Rocker 2021, p. i).

Generation time has not been calculated for the spotted turtle but is likely 20 to 30 years (van Dijk 2011, p. 2). Because spotted turtles are long-lived with high egg and hatchling mortality, population persistence relies on high adult and subadult survivorship, and increases in adult mortality can have large, lasting negative impacts on populations (Howell and Siegel 2019, p. 39). In a population viability analysis for two small, isolated populations of spotted turtles, an added reduction in adult survival (modeled as annual catastrophic events, such as road mortality) increased the probability of extirpation of each population over a 150-year timeframe from 20 percent and 24 percent to 93 percent and 94 percent, respectively (Howell and Siegel 2019, p. 39).

Reproduction

Adults mature between 7 to 12 years of age (Figure 3) (Litzgus 2006, p. 281; Feng et al. 2019b, p. 7). During courtship, the male spotted turtle chases the female and may bite her viciously. In Ontario, to the north, nesting season starts slightly later than the other parts of the species' range, in mid to late June (Litzgus and Brooks 1998a, p. 252). In Pennsylvania, courtship and mating occur from March to early May, and nesting begins in June (Ernst 1970, p. 228). In a recent study conducted in Massachusetts, nesting occurred primarily in June (Garrison et al. 2023, p.

563). In the southern part of the range, in South Carolina, the nesting season begins slightly earlier, in mid-May (Litzgus and Mousseau 2006, p. 132), indicating a latitudinal gradient.

Female oviposition occurs mainly in the evening or at night (Ernst 1970, p. 229; Litzgus and Brooks 1998a, p. 252; Litzgus and Mousseau 2006, p. 132; Garrison et al. 2023, p. 563). Females appear to have strong fidelity to nest substrate but not necessarily nest site location (Rasmussen and Litzgus 2010b, p. 47). Nests are flask shaped, approximately 4.5 to 6 cm (1.77 to 2.36 inches (in)) deep, with a plug of hard earth (Ernst 1970, p. 229). Mean clutch size decreases from north to south, measured as 5.3 eggs in Ontario (Lizgus and Brooks 1998b, p. 257), 3-6 eggs in Massachusetts (Garrison et al. 2023, p. 563), 3.58 eggs in Pennsylvania (Ernst 1970, p. 231), 2.8 eggs in South Carolina (Litzgus and Mousseau 2006, p. 135), and 2.1 eggs in Georgia (Chandler et al. 2022, p. 273). In Ontario and Pennsylvania, clutch size is positively correlated with female body size, with a slight correlation between egg size and female body size only in Pennsylvania (Ernst 1970, p. 228; Litzgus and Brooks 1998a, p. 252; Litzgus and Mousseau 2006, p. 132). In Ontario, correlations adjusted for body size indicate trade-offs between clutch size and egg mass, length, or width (Litzgus and Brooks 1998a, p. 252). Spotted turtles in the northern portion of its range are similar to other northern species of turtles in having more delayed maturation, larger body and clutch sizes, and eggs that are relatively smaller (to body size) than those in populations of turtles that occur within southern states (Litzgus and Brooks 1998a, p. 252).

A positive relationship between spotted turtle body condition and both clutch mass and egg size exists, although there appears to be no association between female body condition and reproductive output (Litzgus et al. 2008, p. 86). Females in poor condition and females in good condition both produce more eggs (larger clutch sizes) than females in intermediate condition, indicating that good body condition has implications for greater reproductive over time, but that within a given reproductive season, reproductive investment may not immediately be affected by energy reserves (Litzgus et al. 2008, p. 86; Rasmussen and Litzgus 2010b, p. 47).

Many females do not lay eggs every year. Each year, the percent of females found to be gravid has varied from 58 percent to 100 percent (Litzgus and Mousseau 2006, p. 132; Chandler et al. 2022, p. 271). There is no evidence that females lay more than one clutch per year in the northern parts of the range (Ontario or Pennsylvania) (Ernst 1976, p. 28; Litzgus and Brooks 1998a, p. 252). Most females in Ontario do not lay eggs every year, and some (16 percent) did not lay for three consecutive years, although larger females lay more frequently (Litzgus and Brooks 1998a, p. 252). However, in the southern part of the range (South Carolina and Georgia), females often produce a second and sometimes third clutch (Litzgus and Mousseau 2003, p. 17; Chandler et al. 2022, p. 268). Clutch frequency appears to be independent of body size (Litzgus and Mousseau 2003, p. 19).

Although individual clutch sizes decrease between northern and southern spotted turtles, total annual reproductive output may be consistent across the range due to southern populations being able to lay multiple clutches (Litzgus and Mousseau 2003, p. 17). Additionally, southern populations may be capable of exceeding reproductive output of the northern populations (Chandler et al. 2022, p. 268).

Spotted turtles exhibit temperature dependent sex determination. Eggs incubated between 22.5 to 27 °C (72.5 to 80.6 °F) produce mostly males, while eggs incubated at 30 °C (86 °F) produce all females (Ewert et al. *in* Valenzuela and Lance 2004, p. 23; Ewert and Nelson 1991 *in* Ernst and Lovich 2009, p. 219).

Incubation ranges from 70 to 83 days (Ernst 1970, p. 228). In Pennsylvania, the middle part of the range, nests were laid in June (June 2 to 29); the earliest hatching occurred on August 18 (Ernst 1970, p. 228). In southern Georgia in 2018 and 2020, nesting took place from May 8 to June 10 for the first clutch and out to July 19 for the third clutch (Chandler et al. 2022, p. 272). Limited data from Florida indicates that the reproductive season at the southern limit of the species range may begin over a month earlier than in southern Georgia, highlighting the variability in reproductive ecology even across a relatively short latitudinal distance (Chandler et al. 2022, p. 268).

While nests hatch in the late summer or early fall, hatchlings may emerge later. Hatchlings emerge mostly at night or in the morning (Ernst and Lovich 2009, p. 219). However, hatchlings may overwinter in the nest in the northern parts of the range (noted in Pennsylvania, and North Carolina) (Ernst and Lovich 2009, p. 219).

Size and Growth

Latitude appears to influence body size and age at maturity. Spotted turtles in the northern portion of their range are larger relative to southern populations, and northern individuals also reach sexual maturity at a larger size (carapace length approximately 103 mm (4.06 in) for females and 105 mm (4.13 in) for males) and estimated age (12 to 15 years for females and 11 to 13 years for males) than southern populations (Litzgus and Brooks 1998b, p. 773).

Spotted turtles grow rapidly as juveniles, but their growth rate slows once they reach maturity, although they grow more after maturity than other species such as painted turtles (*Chrysemys picta*) and red-eared sliders (*Trachemys scripta*) (Ernst 1975, p. 313). Plastral length can increase 7.5 mm/year (yr) (0.30 in/yr) during an individual's first through fifth years of growth, and this rate declines each growing season (second to sixth, 10.6 to 4.9 mm (0.42 to 0.19 in)) until the seventh season, when it increases again (7.7 mm (0.30 in)), which has been postulated to reflect a surge in growth immediately before sexual maturity is reached, although this is based on a small sample size (Graham 1970, p. 88). How much an individual grows in its first season is dependent on its hatch date; hatchlings that overwinter in the nest and emerge in the spring grow larger because they have a more extensive growing season than those that hatch later in the summer (Ernst 1975, p. 313). In southern Pennsylvania, the usual growth period is approximately 1 April to 30 June, approximately 91 days (Ernst 1975, p. 313). The growth period appears to be limited by water temperature (Ernst 1975, p. 313). While males and females do not grow at different rates, growth rates are inversely related to body size, and individual variation in growth rate is high (Litzgus and Brooks 1998b, p. 773).

2.4 Diet

Spotted turtles are omnivorous scavengers and have been observed eating both plant and animal foods (Ernst 1976, pp. 27–28; Ernst and Lovich 2009, p. 220). Spotted turtles appear to be most dependent upon macroinvertebrates but easily detect and consume carrion when available. Vegetation appears to have minimal importance to the spotted turtle diet (Rasmussen et al. 2009, p. 288). Plants include stems of aquatic grasses (Gramineae), wild cranberries (*Vaccinium* sp.), the leaves and seeds of other plants, and filamentous green algae (*Chlorophyta*). They also eat invertebrates, including ants, beetles and their grubs, the larvae of moths and butterflies, crickets and grasshoppers, millipedes (Diplopoda), spiders (Arachnida), slugs and snails (*Helix* sp.), and small crustaceans such as isopods and crayfish (*Cambarus* sp.), as well as benthic invertebrates, including aquatic insects (adults, larvae, and nymphs). They also eat or scavenge for tadpoles and juvenile anurans, salamanders (*Ambystoma maculatum*), fish (*Lepomis macrochirus*, *Catostomus commersoni*, *Ictalurus melas*, *Cyprinus carpio*, and *Notropis*).

Spotted turtles actively seek food by probing algae and aquatic vegetation with their snouts. Spotted turtles do not appear to feed on land; however, terrestrial insects that may have fallen onto the water's surface have been reported as food (Ernst 1976, pp. 27–28).

In summary, like other North American freshwater turtles, spotted turtles are long lived species with individuals living at least 30 years but estimated to live up to 110 years old. Spotted turtles reach sexual maturity at a moderate age (7 to 13 years in males, 7 to 15 years in females) compared to other wetland turtle species, and they have comparably high adult survivorship and low reproductive output. Because they are long-lived with high egg and hatchling mortality, population persistence relies on high adult and subadult survivorship, and increases in adult mortality can have large, lasting negative impacts on populations. Females do not nest every year and northern populations lay only one clutch a year while southern populations can lay multiple clutches. This species has temperature dependent sex determination with females produced at higher temperatures. The species is an omnivore feeding mostly on aquatic invertebrates.

2.5 Habitat and Movements

Habitat

Generally, spotted turtles require wetland habitats with clear, clean water, soft substrate, and aquatic vegetation adjacent to accessible upland habitats (Ernst and Lovich 2009, p. 214). Throughout the year, spotted turtles can exploit a wide variety of mostly freshwater, shallow, wetland habitats, including sphagnum swamps, wooded swamps (with red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), black tupelo (*Nyssa sylvatica*), as well as other tree species), small ephemeral and permanent pools, bogs, fens, wet meadows, cattail marshes, sedge meadows, small woodland streams, and drainage ditches, as well as the edges of bays and ponds and tidally influenced brackish streams (Ernst and Lovich 2009, p. 214; Joyal et al. 2001, p. 1755). They sometimes use different wetlands in different parts of the year, moving to new areas depending on the season and local conditions (Beaudry et al. 2009, p. 642; Joyal et al. 2001, p. 1759). Spotted turtles may be able to tolerate seasonal or occasional seawater influence, but the use of brackish environments may be a response to a loss of preferred freshwater habitat (Willey et al. 2022, p. 13). Observations of spotted turtles occurring or residing in brackish environments have been reported from Georgia, North Carolina, Maryland, Delaware, and Massachusetts (Neil 1958, p. 20; Schwartz 1961, p. 18; O'Dell et al. 2021, p. 306; Stevenson et al. 2015, p. 138).

In Ontario, a population of spotted turtle was studied in a partially mined peatland that became flooded by beaver (*Castor canadensis*); beavers were found to benefit spotted turtles in Pennsylvania, also (Yagi and Litzgus 2012, p. 179; Nagle et al. 2022, p. 5). In western Ontario, researchers found spotted turtles to prefer habitat types that contained open wetlands, meadow marsh, woody wetlands, and open uplands (Rasmussen and Litzgus 2010a, p. 90). In Maine, spotted turtles are more often in wetlands with greater emergent cover, wetland size, hydroperiod, sun exposure, and proximity to hibernation sites (Joyal et al. 2001, entire; Beaudry et al. 2009, p. 642). In Maryland, spotted turtles occupy vernal pools and complexes, flooded forests adjacent to marshes, wet fields, and puddles (Ward et al. 1976, p. 62). In northwest Ohio and southern Michigan, spotted turtles were found in seasonally wet prairies, swamp forests, fens, bogs, vernal pools, sedge meadows, and ditches (Refsnider et al. 2022, pp. 1–10; Lee 2023, pers. comm.). In Georgia, spotted turtles are found in backwater creek swamps, river swamps, temporary depressional wetlands, and ditches (Stevenson et al. 2015, p. 138). In Florida, the species may be limited to wooded swamps within pine flatwoods (Berry and Meylan 1992 *in* Ernst and Lovich 2009, p. 214).

Spotted turtles rely heavily on uplands for nesting, dormancy, and migration between wetlands and use a variety of habitat types including mixed forests, clearings, right-of-way, lawns, agricultural fields, road edges, and early successional habitat (Ernst and Lovich 2009, p. 214), and their choice of upland use areas varies. Unlike highly aquatic turtles, spotted turtles spend up to 30 percent of their time on land, generally in upland areas adjacent to wetlands (Ernst and Lovich 2009, p. 214; Joyal et al. 2001, p. 1755; Milam and Melvin 2001, p. 418). Upland dormancy sites are known to range 12 to 80 m (39 to 262 ft) from the nearest marsh (Joyal et al. 2001, p. 1755). In Ontario, a population used gently rolling terrain with exposed igneous and metamorphic rock or covered by a thin layer of drift, with swampy deposits of organic soils (Haxton and Berrill 1999, p. 597). 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, p. 4). In South Carolina, one population used habitat that consisted of seasonally flooded hardwood bottomland swamp (Litzgus and Mousseau 2004a, p. 807). Microhabitats used by spotted turtles vary both spatially across their range and temporally across seasons (Rasmussen and Litzgus 2010a, p. 86).

Nesting habitat is highly variable but generally consists of well-drained, shallow soil or the woody debris of decaying logs and stumps in well-drained clearings within upland habitats or raised hummocks within wetlands (Ernst 1970, p. 229; Litzgus and Brooks 1998a, p. 252; Litzgus and Mousseau 2006, p. 132; Willey et al. 2022, p. 14). In Ontario, nests are also known to be placed in soil on Precambrian Shield rock outcrops (Litzgus and Brooks 1998a, p. 252). In the northern part of the range, nest sites are typically exposed to full sun, while both open and closed-canopy sites are used in other parts of the range (Willey et al. 2022, p. 14). In Maine, females nest in sphagnum mats and hummocks in wetlands, and were also found on one upland rocky outcrop (Beaudry et al. 2010, p. 4). In a recent study conducted in Massachusetts, nests were constructed in clearings associated with transmission line towers and the edge of gravel trails (Garrison et al. 2023, p. 565). In Ohio, nesting has been found to occur in flooded grasslands, fens, swamps, and forested habitats (Refsnider et al. 2022, p. 5), with eggs laid in sphagnum, grasses, rotten logs, and soil. In South Carolina, nests are known to be laid in decaying woody debris and in small piles of soil covered with dead vegetation (Litzgus and Mousseau 2006, p. 137). In Georgia, nests are typically laid on the periphery of wetlands and 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, p. 273).

Anthropogenically-created areas are also used as upland habitat by spotted turtles, such as lawns, gardens, roadsides, causeways, pastures, clearings, and rights-of-way (Willey et al. 2022, p. 14). In one study conducted in southern Maine, 64 percent of the nesting sites used by spotted turtles were anthropogenic, and 29 percent were in areas that had been available less than 5 years (Beaudry et al. 2010, p. 4). Spotted turtle use of these anthropogenic areas indicates that they may quickly recognize and use artificial nesting sites (Beaudry et al. 2010, p. 1). In Massachusetts, spotted turtles nested in disturbed portions of a sandy hayfield (Milam and Melvin 2001, p. 420) as well as on road shoulders, powerlines, gravel pits, and an elevated causeway to a water pumping station (Jones unpublished data *In* Willey et al. 2022, p. 14).

Nest site variation throughout the range may indicate a latitudinal gradient to nesting, but this is unconfirmed (Willey et al. 2022, p. 14).

Spotted turtles have been located in a variety of aquatic conditions, including wetlands within altered, pine tree plantations as well as unaltered forest habitats, in cranberry operations in New England, and in roadside ditches. Thus, aquatic systems even in highly reconfigured landscapes can support spotted turtles, despite variation in disturbance intensity and site-level environmental metrics (O'Bryan 2014, p. ii; Johnson et al. 2016, p. 124). Ditches can provide travel corridors for turtles between upland and aquatic sites and provide access to mates (O'Bryan 2014, p. ii). Thus, the availability of wetland habitats adjacent to upland habitats appears to be more important than the specific configuration or types of habitats available.

Habitat use by spotted turtles differs between the sexes and varies both seasonally and from year to year (Joyal et al. 2001, p. 1755; Litzgus and Mousseau 2004b, p. 804). Spotted turtles use specific habitats in different seasons and have been known to use pools during spring, upland forest habitats during summer, and bogs as overwintering sites (Joyal et al. 2001, p. 1755; Haxton and Berrill 1999, p. 593). In South Carolina, habitat use differed by sexes except for spring when home ranges overlapped for breeding (Litzgus and Mousseau 2004, p. 812). On the Delmarva Peninsula, males were observed entering the water before females for breeding and stayed in the water longer (Liebgold 2023, pers. comm.). Marshes are primarily selected during the spotted turtle's active season, which lasts from shortly after emergence from hibernation in the spring to late summer. Turtles may shift away from marshes and toward bogs or other sites as the season progresses (Haxton and Berrill 1999, p. 593). During the warmest periods of the summer, both males and females estivate in shallow forms in upland habitats or underneath leaf litter (Joyal et al. 2001, p. 1759; Gibbs et al. 2007 *In* Buchanan et al. 2017, p. 689; Buchanan et al. 2017, p. 689).

Habitat composition appears to influence spotted turtle abundance and probability of detection. In a study conducted throughout the eastern portion of the range, spotted turtle abundance was positively correlated with diversity of wetland types at a local scale (30 m (25.26 ft)) (Willey et al. 2022, pp. 5–6; Roberts et al. 2023, p. 6). At a broader scale (7,680 m (4.77 mi)), abundance showed a positive association with wetland ephemerality and hydroperiod diversity. Abundance was strongly negatively associated with road density at 480 m (0.30 mi) and weakly negatively associated with crop cover and imperviousness at the same scale. Probability of detection increased with water temperature (Willey et al. 2022, pp. 5–6; Roberts et al. 2023b, p. 6).

In a Michigan study, spotted turtles selected for emergent wetlands and avoided dry-mesic forests; in this region where vernal pools provide habitat, spotted turtles generally remain near these pools (Coury 2022, p. 5). A study at three sites in Illinois, Virginia, and Maryland, found that generally, fen, sedge meadow, mesic prairie, swamp, and marsh were preferred by spotted turtles, whereas deep open water, closed canopy upland-forest and dry fields were often avoided (Wilson 2002, pp. 76–79).

At a local scale, spotted turtles in North Carolina in a managed pine plantation selected for areas with greater understory canopy cover, pine needle substrate, and higher substrate temperatures, indicating that thermoregulation likely plays a role in habitat selection (O'Bryan 2014, p. ii).

In summary, throughout the year, spotted turtles utilize a wide variety of mostly freshwater, shallow, wetland habitats as well as the edges of bays and ponds and tidally influenced brackish streams. Spotted turtles have been located in a variety of aquatic conditions, indicating that aquatic systems even in highly reconfigured landscapes can support spotted turtles, despite variation in disturbance intensity and site-level environmental metrics. Spotted turtles rely heavily on uplands for breeding, dormancy, and migration between wetlands and use a variety of habitat types including mixed forests, clearings, right-of-way, lawns, agricultural fields, road edges, and early successional habitat and their choice of upland area types varies.

Activity Patterns

Warming water temperatures in hibernacula during late winter and early spring trigger spotted turtles to become active (Litzgus et al. 1999, p. 1352; Ernst and Lovich 2009, p. 214; Ernst 1976 p. 27; Lovich 1988, p. 484). Spotted turtles are mostly active during daylight hours (Ernst 1976, pp. 25–26). Spotted turtles bask in the sun early in the morning until warm and then forage for food. Few individuals have been noted to be active on rainy days (Ernst 1976, pp. 25–26).

Spotted turtles have been observed burrowing into the mud of a waterway's bottom or crawling into muskrat tunnels as darkness falls (Ernst and Lovich 2009, p. 214). However, nesting females are active after nightfall (Ernst 1976, pp. 25–26), and a study of nocturnal movements found that spotted turtles are quite active at night (Hjort et al. 2021, p. 43). Nocturnal movements were not restricted to females or the nesting season, nor did the movements appear to provide thermoregulatory benefits; these movements are hypothesized to increase time that turtles can spend foraging or searching for mates (Hjort et al. 2021, pp. 43–44).

Compared to most North American turtles, spotted turtles have short annual activity cycles (Ernst and Lovich 2009, p. 214). While they are active in most months, they are most active during the spring and cooler months (March through mid-June) (Ernst 1976, p. 26; Ernst and Lovich 2009, p. 214). Thus, spotted turtles in the northern part of their range are more active for longer than those in the south (Haxton and Berrill 2001, p. 606). In southern regions, spotted turtles awake in late February to early March after hibernation but have been observed to emerge as early as mid-January and have been documented as active in all 12 months (Litzgus et al. 1999, p. 1352; Litzgus and Mousseau 2004b, p. 806; O'Bryan 2014, p. 27; Stevenson et al. 2015, p. 140; O'Bryan et al. 2016, p. 7; Chandler et al. 2019, p. 608). 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. Spotted turtles are typically active until late October or early November, depending on their latitude (Ernst 1976, p. 26; Haxton and Berrill 2001, p. 606).

Spotted turtles are found aggregating during the courtship and mating period ranging from late March through June (Ernst 1976, p. 27; Ernst and Zug 1994, p. 100), but also have a fall courtship period in some southern populations (Litzgus and Mousseau 2006, p. 134; Chandler et al. 2019, p. 613). Spotted turtles are known to sometimes aestivate during the hottest parts of the year (when water temperature reaches 30 °C (86 °F)), potentially due to drying wetlands or predator avoidance and not necessarily just high temperatures (Chandler et al. 2020, p. 741). Turtles will aestivate terrestrially in leaf litter, soils, puddles, and under coarse woody debris (Ernst 1982, p. 118; Wilson 1994, p. 14; Milam and Melvin 2001, p. 423). In some southern populations, the species appears to be active year-round (Chandler et al. 2019, p. 613).

Two primary factors appear to influence the spotted turtle's annual activity cycle: water temperature and reproductive drive (Ernst 1976, p. 26). When the water temperature is too low, it affects all of the spotted turtle's typical activities, including feeding, basking, and dormancy, and perhaps limits reproductive activity. Many of the spotted turtle's spring activities are controlled by the reproductive urge when temperatures are typical for the season (Ernst 1976, p. 26).

The spotted turtle's temperature preferences are linked to activity patterns across different states, with activity maximum when their cloacal (internal body) temperatures approach 15 °C (59 °F), which is associated with the initiation of feeding activity, and lowest activity when mean average air temperature first exceeds 22.6 °C (72.7 °F) (Ernst 1976, pp. 27–28; Lovich 1988, p. 483). Previously determined to not forage at temperatures below 14 °C (57 °F) (Ernst 1976, p. 27), spotted turtles have been noted to forage in water temperatures as low as 7.7 °C (45.9 °F) (Rasmussen et al. 2009, p. 287).

In a laboratory setting in Ontario, when offered a thermal gradient, spotted turtles preferred temperatures between 20°C (68°F) and 26°C (78.8°F) (Yagi and Litzgus 2013, p. 205). While no similar study exists for the southern populations, temperatures in Georgia recorded for two populations fell within this range for much of the year; and spotted turtles did not spend significant time regulating their temperatures above that of their environment (Chandler et al. 2020, p. 741). However, female turtles basked more frequently in May during the time surrounding egg development (Chandler et al. 2020, p. 741).

Despite warmer temperatures later in the year, spotted turtles are not as active later in the season, owing to reduced food availability (Lovich 1988, p. 483). Average daily mobility is highest in the spring and gradually decreases, making spotted turtle detection easier earlier in the season than later in the year. Spotted turtles also decrease activity during periods of drought, when standing water is decreased (Rowe et al. 2013, p. 105).

Spotted turtles will move to their overwintering wetlands as water and air temperatures become cool in October through November (Joyal et al. 2001, p. 1760; O'Dell et al. 2021, p. 311).

Home Ranges

Spotted turtles generally have limited home ranges and high site fidelity. Home range sizes vary greatly, from 0.2 to 34.4 ha (0.49 to 85 ac) (Willey et al. 2022, pp. 39–40; see Appendix D). In one study of radio-tagged spotted turtles, individuals traveled overland throughout a season from 0 to 1,680 m (1.04 mi) total distance (Joyal et al. 2001, p. 1755). Spotted turtles typically use multiple wetlands throughout their annual movements, while few populations are known to be limited to just one wetland (Seburn 2012, p. 529; Rowe et al. 2013, p. 105).

Early in the spring, home ranges overlap, and turtles gather for breeding (Litzgus and Mousseau 2004b, p. 811). Spotted turtles are the most active during their nesting season when they will make long nesting movements, and males will travel long distances in search of females (Beaudry et al. 2009, p. 643; Stevenson et al. 2015, p. x). Individuals generally display a year-over-year commitment to their home-range areas. Males have a smaller home-range size (about 5 ha (12.36 ac)) than gravid females (about 16 ha (39.54 ac)). Gravid females travel further distances than males during the breeding season (Litzgus and Mousseau 2004b, pp. 811–813).

A study in the southwestern lower peninsula of Michigan, however, recorded larger home ranges for males (1.54 ha SE ± 0.26 ha); 3.80 ac SE ± 0.64 ac) than females (1.17 ha SE ± 0.15 ha); 2.89 ac SE ± 0.37 ac)), and overall smaller home ranges than other eastern populations at similar latitudes, which appears attributed to vernal pools providing resources that were easily accessible and confinement within the landscape (Coury 2022, p. 5). Previous studies have also recorded greater home range sizes in males than females in Massachusetts, although several have small sample sizes (Graham 1995, entire; Kaye et al. 2005, entire). Males also move greater distances during the breeding season than previously thought (Lovich 1990, p. 67). However, overlap in home ranges between the sexes indicate that males do not have to travel extensively to find mates (Wilson 2002, p. 53). Males may have transient habits based on one study that followed two tracked turtles moving between 0 and 423 meters (0 and 0.26 mi) in 24 hours, moving from water body to water body with overland transit in between, and nearly never returning to previously occupied habitats (Lovich 1990, p. 67).

A wetland in Ontario, Canada, that is bisected by a single, two-lane paved road, supports a small (~22 individuals) population of spotted turtles on one side of the road but not the other, indicating that if enough (10 ha (24.7 ac)) diverse habitat is available, turtles may not regularly move into new habitat (Seburn 2012, pp. 527–529).

Dispersal

Individuals rarely travel more than 2 km (1.24 mi) per year (Litzgus and Mousseau 2004b, p. 811; Seburn 2003, p. 438). In one study conducted in Pennsylvania, spotted turtle regular daily movements were usually less than 20 m (66 ft) and consisted of visits from nocturnal inactive places to basking or feeding areas. On the other hand, foraging turtles were observed moving up to 50 m (164 ft). Males were observed on land up to 250 m (0.16 mi) from water during the mating season, and females were observed on land up to 50 meters (164 ft) from water during the nesting season, evidently looking for suitable nesting sites. The courtship chases lasted 30 to 50 m (98 to 164 ft) (Ernst 1976, p. 30).

Spotted turtles do not show evidence of sex-biased dispersal, unlike several other members of family Emydidae, potentially related to female-female competition and some degree of sex-role reversal exhibited in this species, based on females being the sex with the brighter coloration (Liebgold et al. 2023, p. 8). Genetic structure at the local scale in populations on the Delmarva peninsula revealed that individuals have high relatedness within 18 km (11 mi) but less than expected relatedness at distances greater than 18 km, indicating that spotted turtles rarely disperse beyond 18 km (Liebgold et al. 2023, p. 8). Populations isolated by greater than 18 km (11 mi) are unlikely to interbreed. This also highlights the importance of habitat connectivity.

Hibernation

Spotted turtles often use bogs for hibernation, but they also use deep water pools with good leaf pack, in-pool brush piles, muskrat burrows, subsurface stream channels, and areas beneath tussocks in wet meadows (Oxenrider 2023, pers. comm.). They can be gregarious in hibernacula and typically show strong site fidelity (Haxton and Berrill 1999, p. 593), although not all individuals use the same hibernacula each year, perhaps out of necessity due to resource availability (Rasmussen and Litzgus 2010a, pp. 93–94). Of 18 hibernacula found in South Carolina, single turtles occupied 11 hibernacula, whereas up to 9 individuals shared 7 communal hibernacula (Litzgus et al. 1999, p. 1348). Sphagnum moss hummocks (n = 15) and rock caverns (n = 3) were the two forms of hibernacula found in swamps in southern Ontario (Litzgus et al. 1999, p. 1350). Almost half of the individuals (16 of 34) spent at least two winters in the same hibernaculum (Litzgus et al. 1999, p. 1348). Turtles spend approximately 15 to 89 consecutive days annually in a dormant stage of hibernation (Joyal et al. 2001, p. 1755).

In Ontario, at the northern end of their range, turtles went into hibernacula between mid-September and October when their body temperature was 12 to 16 °C (54 to 61 °F) and came out between mid-April and late May when ambient temperatures were 1 to 5 °C (34 to 41 °F) (Litzgus et al. 1999, p. 1348). Despite highly varied temperatures, varying by 37 °C in 5 days, and ambient air temperatures as low as -35 °C (-31 °F), turtles kept from freezing, maintaining body temperatures between 0.3 to 3.9 °C (33 to 39 °F) with no substantial loss of body mass. During the four winters, the study found no mortality in hibernacula (Litzgus et al. 1999, p. 1348). However, it has been hypothesized that congregation in hibernacula may make populations vulnerable to predation or collection by humans (Nagle et al. 2022, p. 5).

2.6 Habitat Loss, Population Declines, and Abundance Estimates

Modern turtles arose at least 200 million years ago (e.g., Gaffney et al. 1987, p. 289) and these lineages have persisted through significant glacial and warming periods, as well as the Cretaceous-Paleogene extinction event. Still, apparent declines in populations of freshwater turtles and tortoises (including freshwater, brackish water, and terrestrial species) are occurring globally. Despite 200 million years of evolutionary success, it has taken less than 200 years for populations of most freshwater turtle and tortoise species to decline to levels that threaten their future viability (Stanford et al. 2022, p. R722).

Multiple threats, largely associated with human activities (e.g., habitat loss and degradation, invasive species, pollution, and climate change (van Dijk 2011, p. 1)), have increased the vulnerability of turtle populations to extinction in the past two centuries (Buhlmann et al. 2009, p. 117; Stanford et al. 2020, p. R722). Populations of the most threatened freshwater turtle and tortoise species are affected by multiple stressors simultaneously (Rhodin et al. 2018, p. 147), and these threats may be acting synergistically to accelerate rates of population declines.

The IUCN estimates that the spotted turtle has lost half of its population numbers from historical levels due to habitat loss (van Dijk 2011, p. 1). Widespread wetland loss, development and impervious cover, and documented population decline at sites due to habitat loss, fragmentation, and degradation, as well as overcollection and other sources of mortality, support this estimated decline (Willey et al. 2022, p. 6).

Some documented examples of population decline include:

- Georgian Bay, Ontario: A Population Viability Assessment basic stochastic model for the Georgian Bay population predicted a 60 percent chance of extinction in 100 years, but the metapopulation model predicted an 18 percent chance, demonstrating that dispersal is critical for population persistence. Despite no additional mortality from anthropogenic causes, relatively pristine sites are nevertheless at risk of extinction Enneson and Litzgus 2009, pp.1241–1253).
- Point Pelee National Park, southwestern Ontario: The spotted turtle became extirpated from Point Pelee National Park between the 1970s and early 2000s (Browne and Hecnar 2007, p. 425). The cause was attributed to heavy depredation of turtle nests by raccoons, road mortality, habitat succession, and possible chemical contamination (Brown and Hecnar 2007, p. 426). The park also sustained massive loss of forested swamps and shallow wetlands from draining for farmland in the early 20th century, which likely caused a contraction of the local population.
- Various locales in Ontario: The Natural Heritage Information Centre (NHIC) recognizes 109 spotted turtle sites, 81 (74 percent) of which are currently considered historical (i.e., no known records in at least 20 years) and 3 (3 percent) are considered extirpated, despite the submission of hundreds of new records to NHIC in 2013 (COSEWIC 2014, p. v). Therefore, 84 sites are likely extirpated or functionally

extirpated (e.g., when only a few adults are still present). Only 25 sites (23 percent) are currently known to be extant (COSEWIC 2014, p. v). Evidence indicates that several subpopulations, even in protected and pristine areas, have disappeared or are currently in decline (COSEWIC 2014, p. v).

- Maine: A population viability analysis was conducted for six spotted turtle populations at risk of road mortality and found that every population sampled had at least a 30 percent probability (range 30 percent to 98 percent) of experiencing a 50 percent decline in population size within 100 years (Beaudry et al. 2008, p. 2558).
- Rhode Island: The total amount of forested landscape in the state has decreased due to development since 1953. At that time, 65 percent of the state was forested which likely influenced the distribution and abundance of spotted turtles in the state. From 2013 to 2015, spotted turtles were found to occur in only 8 percent of wetlands and had a positive relationship with shallow marshes surrounded by forest (Buchanan et al. 2019b, p. 435).
- Central Maryland: A 50 percent decline was documented in one population over a period of 30 years (1987 to 2017) and was attributed to lack of recruitment caused by increased abundance of subsidized mesopredators (e.g., raccoons) despite being located on protected land (Howell et al. 2019, p. 493). This population was also evaluated using a population viability analysis to consider the effects of road mortality (Howell and Siegel 2019, entire). The analysis estimated that an additional two percent population loss from road mortality would drastically decrease the population's growth rate and lead to predicted extinction within the next 150 years (Howell and Siegel 2019, p. 42).
- Ohio: Ohio has lost over 90 percent of its original wetlands to development (Mitsch and Gosselink 1993 *In* Lewis et al. 2004, p. 69). One study conducted from 1999 to 2000 revealed that of 50 historical spotted turtle wetlands, 8 (16 percent) were developed and no longer habitable (Lewis et al. 2004; pp. 66–67). Of the remaining 42, 2 (5 percent) showed no site-specific threats, with the majority providing only marginal habitat (Lewis et al. 2004, p. 67). Further, all sites were isolated; wetlands are approximately 20 km (12.4 mi) apart in the southwestern part of the state, 5.0 km (3.1 mi) in the northwest, and 30 km (18.6 mi) in the northeast (Lewis et al. 2004, p. 65). Additionally, in a study conducted from 1981 to 2001 in southwestern Ohio, one spotted turtle population was estimated to have declined from 75 spotted turtles in 1990 to 20 in 2001 (Hawkins and Lewis 2002 *In* Lewis et al. 2004, p. 70), a 27 percent decrease over a 20-year period. At a site in Champaign County, the decline of spotted turtle has been well documented (Lovich 1987, pp. 24 - 26). In 1929 as many as 24 individuals were captured in one day but intensive surveys conducted in 1984 and 1985 resulted in only three captures. Habitat at this site was also reduced from 3,450 acres (1,396 ha) to 2.5 (1.01 ha) from dredging, a lowered water table, and

ecological succession (Lovich 1987, pp. 24 - 26). At another site in Clark County, Lewis and Ritzenthaler (1997, pp. 611–614) observed as many as 34 individuals overwintering in a single burrow. In 2017, surveys resulted in 51 captures of only 12 individuals. Spotted turtles were extirpated from an 892.05-acre (361 ha) wetland in Lake County with the last known observation occurring in 1979 (Matson et al. 2017, pp. 16– 20).

- Illinois: Several populations documented since 1927 have been extirpated, leaving only two populations in the state (Feng et al. 2019a, p. 649). However, these two populations appear to be stable (Feng et al. 2019a, p. 648).
- Indiana: In evaluating historical data and aerial imagery, the Indiana Department of Natural Resources identified 63 spotted turtle populations. Of those, 38 (60 percent) of the spotted turtle populations had occurrences dating after 1970. Additionally, individuals from only 13 (21 percent) spotted turtle populations have been observed from 2016-2021. Thus, the number of populations appears to have substantially declined. (INDNR 2021, p. 3).
- Virginia: A 37 percent decline in suitable habitat across a 35-year period was observed at a 577 ha (1,425 ac) known site, and a change in habitat was attributed to increased siltation linked to urban development in the surrounding landscape, leading to succession and drier habitats on site (Wilson 2004, p. 46). Population trend data was not available, but mitigation efforts were recommended to prevent population decline. Subsequently, in 2007, a status assessment was conducted for the species throughout Virginia and concluded that populations across large areas of the state would likely become extirpated due to urban expansion (Mitchell and Buhlmann 2007, p. 10). During the study period (2005 to 2007, 6 of 28 populations were lost to urbanization (Mitchell and Buhlmann 2007, p. 7); populations in rural areas and protected lands were likely secure (Mitchell and Buhlmann 2007, p. 10).

Some examples of stable or increasing populations:

- Georgian Bay Island, Ontario: One of the longest mark-recapture studies found that a population was healthy and stable across a 24-year period (1977 to 2000) (Litzgus 2006, p. 285). 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 (Litzgus 2006, p. 285).
- Massachusetts: Over a 2-year study conducted from 1988 through 1989, a healthy population with an equal sex ratio and successful recruitment with 23 juveniles was observed with all age classes represented (Kaye et al. 2001, p. 72). Their population density was also estimated to be higher than previous reports: 78 turtles over a 2-year period, 18.8 turtles/ha (46.46 turtles/ac) based on 3.2 ac (1.29 ha) of suitable habitat

as compared to that reported by Graham (1995, p. 207–214; 6.7 turtles/ha; 16.56 turtles/ac) and Ernst et al. (1994, p. 221; 0.5 and 79.1 turtles/ha; 97.61 and 195.46 turtles/ac). However, this population since has a highway running through it and has not been reassessed, so current stability is unknown (Jones 2023, pers. comm.).

Three populations were also assessed as part of the regional CSWG effort (Willey et al. 2022, p. 19) (see below) that had been previously studied by Graham (1995, pp. 207–214) and Milam and Melvin (2001, p. 418–427). Two sites are conserved as water supply areas, two are primarily forested, and one has substantial agriculture cover. There has not been a change to the landcover over time, although water levels have fluctuated due to beaver activity, and invasive plant species had invaded a nesting area at one site. Estimates for these sites from 1989 to 1995 were 98, 18, and 43 turtles, and those from 2018 to 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 24 to 40 percent at the third site; though it is possible the population center shifted due to habitat change (Willey et al. 2022, pp. 19–20).

- North Carolina: A spotted turtle population located in a reconfigured landscape with heavy historical anthropogenic influence was found to be healthy and robust (O' Bryan et al. 2016, entire).
- South Carolina: A 4-year study (1999 to 2003) provided evidence of a stable population with presence of multiple age classes, proportion of juveniles, and an equal sex ratio (Litzgus and Mousseau 2004a, entire). The site was relatively undisturbed by anthropogenic effects. This population was also sampled as part of the recent CSWG effort, and turtles were found inhabiting the same areas that were originally surveyed as well as other wetlands on the property (Willey et al. 2022, p. 22).
- Georgia: Two sites have been surveyed annually since 2014 (Chandler, unpublished data *In* Willey et al. 2022, p. 22). 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, p. 274).

Abundance

There are no range-wide estimates of abundance for spotted turtles in the United States; however, the regional CSWG conducted standardized surveys for the species from Maine to Florida to help inform the status and development of a conservation plan. Compilation of spotted turtle records from throughout the eastern part of the range, combined with standardized sampling conducted from 2018–2021 confirms that the species remains extant in a variety of wetland habitats. Despite the myriad of threats facing the species, and habitat and population loss that has occurred over the last two centuries, there are still relatively large and connected spotted turtle populations distributed across the eastern part of the range (see Appendix C for Abundance and Catch Per Unit Effort (CPUE) information from the CSWG). However, they may be absent from heavily fragmented areas and present in low abundances in parts of the range where there is less habitat availability (outside the coastal plain regions) (Willey et al. 2022, p. 9).

The CSWG identified 2,351 delineated sites and conducted surveys at 309 unique sites using standardized visual-encounter and trap-based sampling (Willey et al. 2022, p. 5). In total, 3,399 unique spotted turtles were captured 4,698 times during the sampling period, the majority of which (84 percent) were made by trap. Catch per unit effort (CPUE, captures/functioning trap checks) for the region was 0.12; however, CPUE varied from 0.06 in the southeast states (North Carolina, South Carolina, Georgia, and Florida) to 0.16 in the southern mid-Atlantic states (Delaware, District of Columbia, Maryland, West Virginia, and Virginia). In New England (Maine, New Hampshire, Vermont, Massachusetts, and Rhode Island), the CPUE was 0.14 and in the northern mid-Atlantic states (New York, Pennsylvania, and New Jersey) the CPUE was 0.08 (Willey et al. 2022, p. 5). At least 19 sites sampled had over 100 turtles, and approximately 28 percent of mapped spotted turtle habitat in the eastern U.S. has some level of protection However, only 15.1 percent of the 2,351 delineated sites are more than 50 percent protected (though the level and proportion of protection varies throughout the eastern U.S. (Willey et al. 2022, p. 9).

To complement the broad-scale population assessment in the CSWG, loglinear models were used to estimate site specific population abundances for sites with sufficient trap capture data using a capture-mark-recapture analysis. Sites that had 5 or more turtles captured and had at least 2 recaptures were analyzed; 80 sites met this criteria (Willey et al. 2022, p. 108). Abundance estimates were related to catch per unit effort (CPUE; number of spotted turtles captured in traps/number of trap checks) at each site using linear regression and differences were evaluated for 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). 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. 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 (Willey et al. 2022, p. 109; see Appendix C for eastern U.S. estimates).

In Canada, the total number of spotted turtles is not known with certainty; however, existing sampling efforts provide a mean estimate of approximately 1,840 mature adults from sampled sites alone (range 1,700 to 2,100; 220 throughout southeastern Ontario, 1,170 throughout southwestern Ontario, and 450 throughout the Georgian Bay/Bruce greater area). It is doubtful that many more undiscovered subpopulations occur in southern Ontario; however, there are likely some undiscovered subpopulations throughout central Ontario due to the presence of extensive suitable habitat and the lack of survey efforts in remote areas.

Density estimates for spotted turtles range from 0.05 turtles/ha to 79.6 turtles/ha, although studies vary in methodology used to estimate density (Ontario-Litzgus and Mousseau 2004a, p. 395; MA-Kaye et al. 2001, p. 72; PA-Ernst 1976, p. 28). In western Erie County, Pennsylvania, one study conducted during the spring and summer months from 1998 to 2003 revealed that a 6.25-ha (15.44-ac) site estimated 40 turtles (35-45, 95 percent confidence intervals) (Gray 2004, pp. 21–29). In North Carolina, one study conducted on a reconfigured forested landscape estimated mean adult abundance per km of roadside ditch (approximately 735 km (456.71 mi)) parallel to unimproved forest roads to be 2.1 turtles (95 percent credible intervals (CI): 0.7–5.1 turtles) in February 2012, and 1.6 turtles (95 percent CI: 0.6–3.2) in April 2013, with a total of 280 turtles captured and marked (O'Bryan et al. 2014, p. 10).

3 SPECIES NEEDS FOR VIABILITY

3.1 Individual Level

At the individual level, spotted turtles require suitable conditions to promote growth and survival during each life stage and to successfully reproduce (Table 2). The species requires diverse habitats for different parts of the year: aquatic habitats such as marshes and pools during the active season for foraging and breeding; upland habitats for nesting sites, and aestivation; and suitable locations for overwintering. Individuals need access to mates of mature reproductive age, as well as nesting areas that are sunny and consist of well-drained, shallow soil, sphagnum, or woody debris. Hatchling spotted turtles need cover from predators.

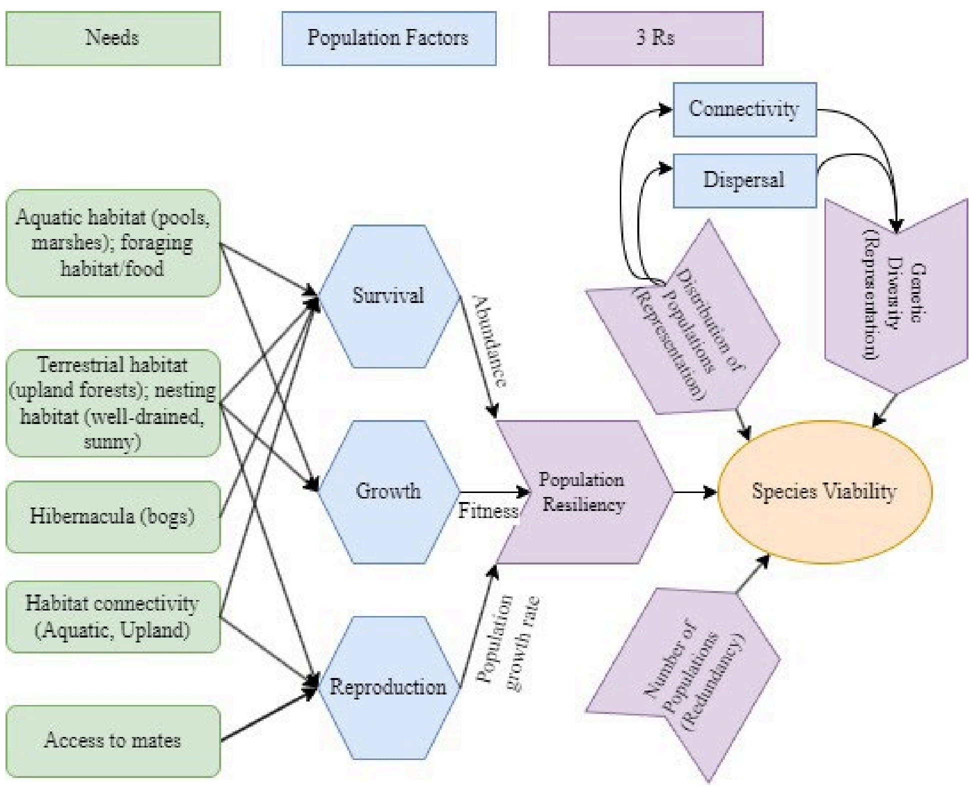

Figure 4. Needs of individual spotted turtles and how these needs relate to species viability.

Table 2. Individual needs of the spotted turtle at each life stage.

Life Stage	Habitat	Needs	Citation
Egg	Nesting	Well-drained substrates (with little or no cover in the northern part of the range)	Ernst 1970, p. 229; Litzgus and Brooks 1998a, p. 252; Litzgus and Mousseau 2006, p. 132; Willey et al. 2022, p. 14
		Undisturbed, stable locations safe from predators/vehicles/agriculture equipment/collection	Yagi and Litzgus 2012, p. 179; Willey et al. 2022, p. 14
Hatchling (to hibernation)	Terrestrial	Varied upland habitats for thermoregulation (basking sites)	Ernst and Lovich 2009, p. 214; Joyal et al. 2001, p. 1755; Milam and Melvin 2001, p. 418
	Aquatic	Pools and open water and associated habitats for foraging and bogs and marshes for overwintering	Ernst 1976, p. 26; Haxton and Berrill 1999, p. 593
Juvenile/ Adult	Aquatic	Freshwater or slightly brackish wetlands, including permanent and seasonal pools, wooded swamps, and wet meadows that provide foraging habitat and overwintering sites	Ernst 1976, p. 26; Haxton and Berrill 1999, p. 593; Ernst and Lovich 2009, p. 214; Joyal et al. 2001, p. 1755; Milam and Melvin 2001, p. 418
	Terrestrial	Upland dormancy and breeding sites within accessible distance from aquatic habitats	Ernst and Lovich 2009, p. 214; Joyal et al. 2001, p. 1755; Milam and Melvin 2001, p. 418
	Nesting	Well-drained substrates with little or no cover in undisturbed, stable locations safe from predators/vehicles/agriculture equipment/collection	Ernst 1970, p. 229; Litzgus and Brooks 1998a, p. 252; Litzgus and Mousseau 2006, p. 132; Willey et al. 2022, p. 14
	Mating	Presence of adult males and gravid females	Ernst 1976, p. 27
	Overwintering	Bogs, marshes, rock caverns in swamps, pools of water with leaf pack, in-pool brush piles, etc.	Haxton and Berrill 1999, p. 593; Litzgus et al 1999, p. 1349; Oxenrider 2023, pers. comm.
	Food	Aquatic habitat with plentiful food resources, including both plant and animal foods (aquatic grasses, filamentous green algae (Chlorophyta), aquatic insect larvae, small crustaceans, snails, tadpoles).	Ernst 1976, pp. 27-28
All	Habitat Connectivity	Terrestrial and aquatic habitats (wetlands, including permanent and seasonal pools, wooded swamps, wet meadows and uplands) in an intact and unfragmented mosaic of marshes, swamps, and drier prairies, that include upland nesting areas, pools,and suitable hibernacula; unfragmented by roads, minimal development and impervious surface.	Joyal et al. 2001, p. 1755; Meylan 2006, p. 231; Beaudry et al. 2010, p. 1; Chandler et al. 2019, p. 602

3.2 Population Level

Resilient spotted turtle populations require the needs of individuals to be met at a broad scale, both spatially and temporally. Due to the spotted turtle's low reproductive output, spotted turtles depend on high rates of adult survival for population persistence, making habitat quality highly important (Lewis et al. 2004, p. 69). Populations need both aquatic and upland habitats, with safe paths between them. Populations also need adequate genetic diversity to prevent inbreeding and a reduction of fitness in order to be resilient against stochastic events.

3.3 Species Level

For a species to be viable, there must be adequate redundancy and representation. Populations must be resilient, with a relatively widespread distribution and high connectivity for a species to have adequate redundancy. Redundancy improves with increasing numbers of populations, either through natural means or reintroduction of individuals produced in captivity; increased distribution of individuals across the species range; and increased connectivity, either through natural or human-facilitated means, that allows connected populations to repopulate each other after catastrophes. Representation improves with the persistence of populations spread across the range of genetic diversity and with ecological diversity within the species. Long-term viability will require resilient populations to persist into the future.

4 INFLUENCES ON VIABILITY

In this section, we describe the threats on the needs and viability of the spotted turtle. We also discuss positive influences on the viability of the species.

We identify land use change and climate change as the two main influences affecting viability (Figure 5). A recent evaluation of threats using analyses and state and expert input similarly determined the major threats to the spotted turtle are development, wetland loss, climate change, and collection (Willey et al. 2022, p. 7).

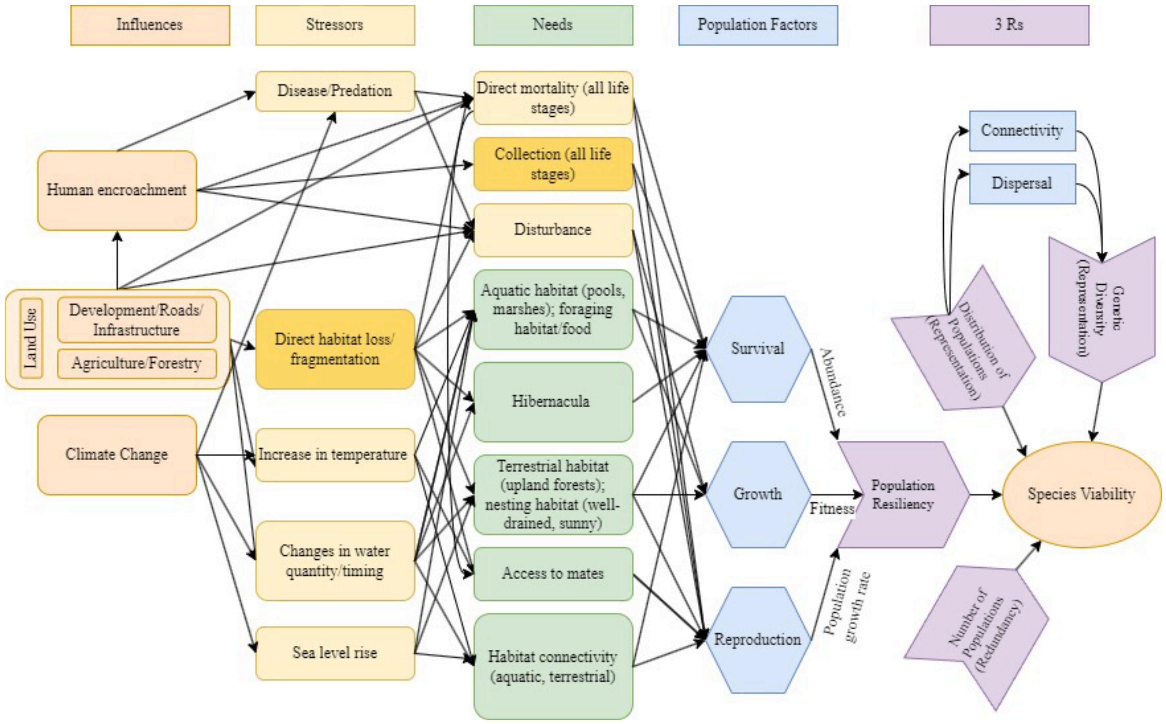

Figure 5. Stressors (yellow) to the needs (green) of the spotted turtle and the influences (pink) that drive those threats. Major threats identified in dark gold.

4.1 Land Use and Management

Habitat Loss, Fragmentation, and Alteration

The direct loss of wetland habitats has occurred over at least the past two centuries via filling, dredging, draining, development, and fragmentation presenting a major threat to the spotted turtle. Between the 1780s and 1980s, the conterminous United States is estimated to have lost 53 percent of its wetlands (Dahl 1990, p. 16), with the upper midwest and upper mid-Atlantic states seeing higher percent loss (Figure 6). Much of the Atlantic Coastal Plain region once had expansive freshwater wetlands that were extensively drained by the 1980s via networks of ditches to support agriculture, forestry, and peat mining (Richardson 1983, pp. 628–630).

Studies addressing wetland trends within the range of spotted turtles were used to estimate that 179,500 ac (72,641 ha) of vegetated palustrine wetlands (selected to broadly represent spotted turtle habitat) have been lost between 1950 and the mid-2000s (Willey et al. 2022, pp. 133–134). This estimate does not include smaller, isolated wetlands like vernal pools and ditches or ephemeral wetlands that are not mapped, and the estimate only includes 12 of the 21 states within the spotted turtle range; however, it also likely includes wetland types that are unsuitable habitat for spotted turtles (Willey et al. 2022, pp. 134–135).

In southern Ontario and prior to European settlement (ca. 1800), there were approximately 2 million ha (20,000 sq km) of wetlands (25 percent of the total area); by 1967, only 637,020 ha (6,370 sq km) remained (8 percent of the total area), and by 2002 this was furthered reduced to 560,000 ha (5,600 sq km) (7 percent of the total area; Ducks Unlimited 2010 *In* COSEWIC 2014, p. 16). Overall, approximately 1.4 million ha (14,000 sq km) or 72 percent of pre-settlement wetlands in this region that are greater than or equal to 10 ha (0.1 sq km) in size were lost by 2002 (Ducks Unlimited 2010 *In* COSEWIC 2014, p. 16). Development, agricultural lands, forest clearings, urban fields, and clearings for hydro and transportation rights-of-way were the primary land uses accounting for 94 percent of wetland loss in southern Ontario (Ducks Unlimited 2010 *In* COSEWIC 2014, p. 16).

The true extent of spotted turtle habitat loss throughout its range is unknown.

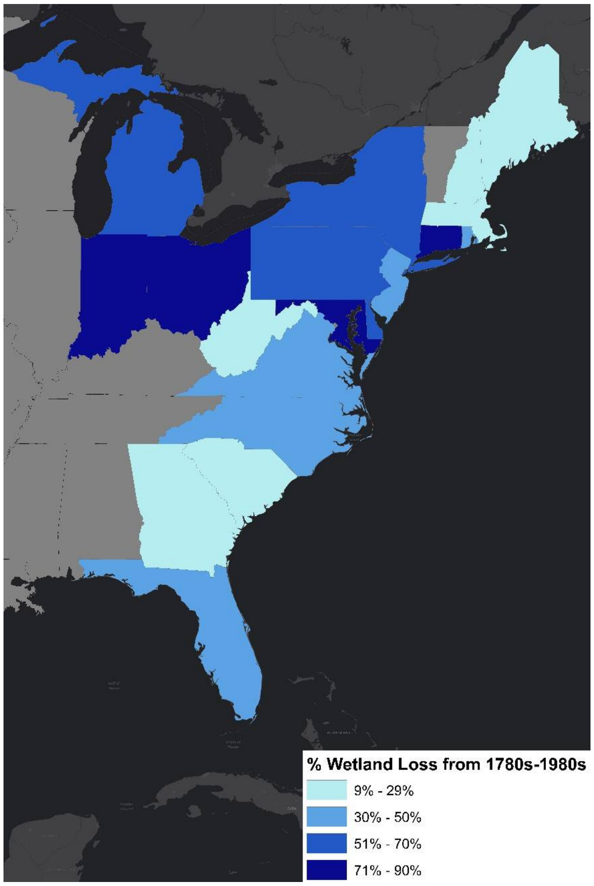

Figure 6. The estimated percent loss of wetlands for states with spotted turtles between the 1780s and 1980s. Vermont and Illinois were excluded due to their low numbers of populations and their status of the edge of the species range. From Willey et al. 2022, p. 133; source: Dahl 1990, p. 6.

Habitat fragmentation and alteration due to human development and roads has ranked as the largest threat to the spotted turtle in a recent survey of turtle conservationists familiar with the species (Meck 2020, p. 5; Willey et al. 2022, p. 23) and is identified as a major threat by all 21 states in the spotted turtle's range for this analysis (USFWS 2023, unpublished data). Fragmentation increases barriers to dispersal and makes remaining populations smaller and more vulnerable to catastrophes, deleterious effects of inbreeding, and environmental and demographic stochasticity. Habitat quality is especially important to spotted turtles because they are long-lived and typically exhibit low recruitment rates, even without additional threats (Lewis et al. 2004, p. 69). Spotted turtle abundance is negatively correlated to road density within 480 m (1,574.8 ft) of a site and sites with more recent observations had less urbanization (15.6 percent versus 19.6 percent impervious surface), and greater forest in the surrounding landscape, than sites where spotted turtles were documented historically but not recently (Willey et al. 2022, p. 7). Due to their dependence on both wetlands and uplands for different life stages and activities (see Section 2.4), these habitat types need to be accessible for spotted turtles to move between them throughout their annual cycle. While spotted turtle home ranges are relatively small, they make significant upland excursions to use open nesting grounds in otherwise forested areas, putting them at risk of road mortality and other threats (Beaudry et al. 2010, p. 1). As such, a landscape strategy is needed to conserve habitat, including conserving wetlands in groups, safeguarding small wetlands, and maintaining extensive terrestrial buffers around and between individual wetlands (Joyal et al. 2001, p. 1755; Chandler et al. 2019, p. 602).

Habitat alteration and restoration carried out for conservation purposes can also impact spotted turtles, potentially in negative ways. Clearcutting to create early successional habitat has unknown long-term effects on spotted turtles, but spotted turtles are known to utilize mature bottomland forests (Buchanan et al 2017, p. 688; Nagle et al. 2022, p. 5). However, one study in Rhode Island found few short-term effects when clear-cutting was carried out near a wetland complex (Buchanan et al. 2017, entire). The authors recommend that habitat alteration activities take place outside of the active season of this species (Buchanan et al. 2017, p. 688).

Similarly, the restoration of salt marshes is becoming a priority in many coastal areas, as salt marshes have been replaced over time with freshwater wetlands through tidal restrictions; salt marshes provide ecological benefits (water quality, erosion control, etc.) and mitigate the impacts of climate change (O'Dell et al. 2021, p. 301). However, salt marsh restoration along the coastal areas of the spotted turtle range may displace spotted turtles who require freshwater habitats. For example, salt marsh restoration on Nantucket Island in Massachusetts was not attributed to changes in spotted turtle home range size, but the turtles did shift into neighboring freshwater habitats, indicating the need to protect these wetlands (O'Dell et al. 2021, p. 301).

Habitat fragmentation and alteration due to development and other land use has occurred in the past, is occurring currently, and will continue to occur in the future. The magnitude of the threat on species viability is high. The following threats (i.e., road mortality, agriculture/mowing, hydrologic alterations, and invasive species and successional changes) are associated with development and contribute to the high magnitude of the threat.

Road Mortality

The complex movement ecology and habitat requirements of spotted turtles make their populations especially vulnerable to road or railway mortality. Over the course of a year, they typically visit multiple wetlands to forage, mate, thermoregulate, and overwinter (Joyal et al. 2001, p. 1759), requiring frequent overland migrations and road crossings. Spotted turtles are frequently documented on roadways (Seburn 2012, p. 529). One study of two small, isolated populations of spotted turtles in Maryland, found that adding road mortality (loss of two adults annually) to a population viability analysis increased the probability of quasi-extinction within 100 years by 69 percent and 70 percent, respectively (Howell and Seigel 2019, p. 39).

Populations that occur and tend to remain within large wetlands may be somewhat protected from the threat of road mortality, and identifying and protecting these types of populations with a potentially higher probability of remaining extant should be a conservation priority (Rowe et al. 2013, p. 105; Seburn 2012, p. 529).

Information on road mortality of spotted turtles in Canada help provide insight on this threat to the species and potential beneficial mitigation measures.

- Although one study in Canada reported that individuals tracked (N = 5, representing 31 percent of estimated subpopulation) from June to late September did not seem to cross a road bisecting the wetland (Seburn 2012, p. 527), other subpopulations adjacent to roads in Canada are known to experience high annual losses of individuals (Gillingwater 2007, unpub. data; Riley et al. 2013, pers. comm. *In* COSEWIC 2014, p. 33).
- Observations at one protected area bisected by a road between 2003 and 2007 found three to nine adults dead on the road annually; however, actual road mortality levels are likely higher given that these were incidental observations recorded during travel to the research site and only during early spring rather than through the full active season for spotted turtles (Gillingwater unpub. data *In* COSEWIC 2014, p. 33). Using radio-telemetry data from this subpopulation, the estimated probability of an adult spotted turtle crossing and being killed on the road was 7.7 percent (Enneson 2009 *In* COSEWIC 2014, p. 33). Wildlife passages were recently installed at this site in 2012 and are being monitored for effectiveness and use. Snapping turtles have been confirmed using the passages and it is possible that spotted turtles are also using the new crossing structures (Gillingwater pers. comm. 2013 *In* COSEWIC 2014, p. 33). Since the installation of fencing and culverts, only three spotted turtle mortalities have been reported along this road between 2012 and 2013 (including one adult, one juvenile and one hatchling; OMNRF pers. comm. 2014 *In* COSEWIC 2014, p. 33).

Efforts to mitigate this mortality risk for other wildlife by way of installing culverts and other crossing structures along roadways and railways have also proven successful in Massachusetts and Virginia (Donaldson 2005, p. 29; Pelletier et al. 2005, pp. 419–421; Kaye et al. 2005, pp. 430–431). In southwest Ontario, road surveys were conducted 5 years pre- and post-construction, and more than 5 m (15 ft) of exclusion fencing was installed along a causeway in 2008–2009, followed by use of motion activated cameras and antennas to detect movement of pit tagged individuals through culverts installed between 2012 and 2015 (Markle et al. 2017, pp. 345–349). Turtle and snake abundance was 89 percent and 53 percent lower, respectively, in completely fenced road sections than in unfenced sections, and abundance was 6 percent and 10 percent higher, respectively, between partially fenced and unfenced sections (Markle et al. 2017, p. 347). Spotted turtles were not observed using the culverts during the study but several other freshwater turtle species were. In New Jersey, a wildlife passage system was constructed in 2019 and consists of two under-road tunnels and fencing that guides animals to the tunnels and prevents them from entering the roadway. The goal of the project was to reconnect fragmented patches of wetland habitat and provide a safe passageway for animals to move between the wetland areas. During two years of post-construction monitoring conducted in 2019 and 2020, they found 100 percent of target species road mortalities within the fenced section of roadway, and a number of full crossings through camera-monitored under-road tunnels (B. Zarate 2023, pers. comm.).

In summary, road mortality occurs from development and is one of the greatest threats to the species due to removal of adults from populations. Efforts to mitigate this mortality risk by way of installing culverts and other crossing structures, such as fencing along roadways and railways, have proven successful for spotted turtles in Ontario, Massachusetts, and Virginia. This threat has occurred historically but has likely increased and will continue to increase in the future throughout many geographic locations across the spotted turtle's entire range due to development.

Agriculture/Mowing

When wetlands are adjacent to agricultural fields, pastures, and yards, spotted turtles are subject to injury from farm equipment, livestock, and potentially lawn mowers during aestivation, upland movements, or migration (Meylan 2006, p. 232; Oxenrider 2023, pers. comm.). Spotted turtle injuries from mowers are known to occur in Pennsylvania (Ernst 1976, p. 31). Wetland habitat can be degraded by cattle (Oxenrider 2023, pers. comm.). At six sites in Maine from 2004 to 2006, most nest sites (64 percent, n = 14) were anthropogenic in nature (75 percent when combined with a previous Maine study with spatial overlap: Joyal et al. 2001, p. 1,759; n = 28 nests). For example, five turtles nested in backyards and two nested in agricultural settings (a hay field and a horse pasture) (Beaudry et al. 2010, p. 5). These results were consistent with a prior study in Maine where most nests (86 percent, n = 14) were found in human altered sites such as yards, roadsides, and pastures (Joyal et al. 2001, p. 1759). In another study in Massachusetts, spotted turtles used seasonal pools connected by agricultural ditching (Milam and Melvin 2001, p. 422).

Adult female spotted turtles from at least one site in southwestern Ontario have been killed by agricultural machinery when nesting in fields adjacent to wetlands (Yagi 2013, pers. comm. *in* COSEWIC 2014, p. 40). Spotted turtles were also killed by agricultural machinery in Massachusetts (Milam 1997 *In* Willey 2022, p. 14). It is likely that other subpopulations adjacent to agricultural lands in other portions of the spotted turtle's range are also at risk of annual adult mortality from agricultural practices. Overgrazing by livestock has also been reported as a threat to this species (COSEWIC 2004 *in* COSEWIC 2014, p. 40).

While spotted turtles spend approximately 30 percent of their time in the upland environment, movement is generally limited to upland areas adjacent to wetlands. While agriculture can occur adjacent to wetlands, there are few studies documenting how frequently mortality occurs. Five of 21 states (24 percent) in the species' range cited agriculture as a threat to spotted turtles (USFWS 2023, unpublished data). This threat has occurred historically, is occurring presently, and will continue to occur in the future throughout its range. The magnitude of the threat is likely low but contributes to the high magnitude threat of land use as a whole.

Hydrology

As mentioned previously, wetlands have been lost or hydrology has been altered through filling, dredging, draining (for agriculture and forestry), and development. Hydrological alterations of a wetland may cause the system to dry out and become too shallow, or inversely become too deep for spotted turtles (O’Dell et al. 2021, p. 301). Residential, commercial, and energy development may alter spotted turtle wetland hydrology in a variety of ways. Wright et al. (2006, entire) provides an extensive review of indirect impacts to wetlands from development, including hydrologic changes and water quality stressors, most of which could lead to adverse impacts to spotted turtle habitats and populations. Impacts also may originate in the adjacent uplands and surrounding landscape and can include increased stormwater and contaminated surface runoff (including lawn treatments and parking lot contaminants), increased sedimentation from construction, and alteration of underlying hydrologic regimes. Roads may act as dams, either flooding or drying out adjacent wetlands.

Some of the wetland habitats spotted turtles use such as bogs and fens are sustained by groundwater sources that are sensitive to changes in subsurface water supplies. Development occurring in groundwater recharge areas results in increases in impervious surfaces, compaction of soils, and stormwater conveyance that all contribute to reductions in groundwater recharge (Wright et al. 2006, p. 22). Impervious surfaces also can increase the flow of surface water runoff into wetlands and temporarily increase water levels (Feaga et al. 2012, p. 1019). Alteration of hydrology can also lead to an increase in woody vegetation, a change in herbaceous vegetation, and succession in the wetland resulting in loss of wetland habitat over time.

Drainage ditches are often used by spotted turtles where they occur near upland habitat (O’Bryan et al. 2014, p. 10); however, dredging of ditches does occur and could cause mortality of spotted turtles. For example, in North Carolina, dredging occurs approximately every 25 years but occurs on a very small proportion of available ditches in any year. A study conducted in that state from 2012–2013 did not observe mortality associated with ditch maintenance and concluded that turtles likely can move away from equipment during the active season (O’Bryan 2014, p. 12).

Flooding caused by beavers in a historically harvested area for peat in Canada resulted in the creation of additional habitat that spotted turtles exploited and preferred over the drainages they had previously been using. However, while the flooding appeared to allow turtles to remain active longer by acquiring more energy reserves, the flooding may have impacted the availability of suitable nesting sites (Yagi and Litzgus 2012, p. 188).

The threat of hydrological alterations to spotted turtles and their habitat has occurred historically, is occurring presently, and will continue to occur in the future throughout its range. The magnitude of the threat is likely moderate but contributes to the high magnitude threat of land use overall. Flooding from beavers and drainage ditches may alter hydrology but can also be used by spotted turtle.

Invasive Species and Successional Changes

Invasive plant species such as common reed (*Phragmites* sp.), purple loosestrife (*Lythrum salicaria*), glossy buckthorn (*Rhamnus frangula*), and others, and native species such as red maple (*Acer rubrum*) are altering habitat for the spotted turtle throughout the species’ range by altering stream wetland hydrology, choking out native species, affecting soil composition and hydrology, causing changes in flora and fauna composition and diversity, and reducing water quality downstream (Lewis et al. 2004, p. 69; Oxenrider 2023, pers. comm.; Willey et al. 2022, p. 24).

Phragmites sp. (common reed) is particularly problematic in the coastal areas of the species' range and Ontario. It is an aggressive plant that grows rapidly and displaces naturally diverse vegetation communities with dense monocultural stands (Wilcox et al. 2003, p. 665; Gilbert et al. 2014, p. 78). Given the height (greater than 5m (16.40 ft)), density (greater than 95 percent) and rapid expansion (approximately 10 cm (1.97 in)/day) of *Phragmites* stands (Wilcox et al. 2003, pp. 668–674); Jodoin et al. 2008, p. 455; Gilbert et al. 2014, p. 83), this invasive plant poses several problems for spotted turtles. For example, turtle nesting sites can be quickly overtaken within a few short weeks, causing nests to become shaded and overgrown with plant roots, which reduced incubation temperatures and hatching success (Bolton and Brooks 2010, p. 241). Reduced incubation temperatures may be further problematic as it could skew subpopulation sex ratios if nest sites continually become shaded during the incubation period (Vogt and Bull 1984 In COSEWIC 214, p. 36; Janzen 1993, p. 335; Janzen and Morjan 2001, p. 76; Kolbe and Janzen 2002, p. 276). Additionally, mortality of hatchlings overwintering in the nest chamber increases when greater vegetation cover limits snow accumulation and thus reduces insulation from cold temperatures (Weisrock and Janzen 1999, pp. 99-100). The density and height of *Phragmites* sp. stands also limits turtle basking and movement (Gillingwater 2013, pers. comm. *In* COSEWIC 2014, p. 36; Mifsud 2013 *In* COSEWIC 2014, p. 36) and reduces the availability of habitat (Gilbert 2012, p. 22; Gillingwater 2013, pers. comm. *In* COSEWIC 2014, p. 36; Mifsud 2013 *In* COSEWIC 2014, p. 36). In Canada, few to no turtles were found in *Phragmites*-dominated areas compared to non-*Phragmites*-dominated areas that were surveyed with the same effort (Davy 2014, pers. comm. *In* COSEWIC 2014, p. 36; Gillingwater 2014, pers. comm. *In* COSEWIC 2014, p. 36), and that small numbers of both spotted turtles and other turtle species have been observed stuck or dead within dense stands of *Phragmites* (Davy 2014, pers. comm. *In* COSEWIC 2014, p. 36; Mackenzie et al. 2014 *In* COSEWIC 2014, p. 36).

The threat and persistence of invasive species encroachment into spotted turtle habitat has occurred historically, is occurring presently, and will continue to occur in the future throughout its range. The magnitude of the threat is likely low but contributes to the high magnitude threat of development.

4.2 Climate Change

Various emissions scenarios suggest that by the end of the 21st century, average global temperatures are expected to increase 0.3 °C to 4.8 °C (0.5 °F to 8.6 °F), relative to the period 1986 to 2005 (IPCC 2014, p. 10). By the end of 2100, it is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales, and it is very likely that heat waves and extreme precipitation events will occur with a higher frequency and intensity (IPCC 2014, pp. 15–16).

Emissions scenarios predict that average temperatures will generally increase more at higher latitudes, with larger increases both over time and under a higher climate scenario (Figure 7). Average annual precipitation is generally expected to increase in the entire range of the spotted turtle (Figure 9); however, rainfall amounts and timing are generally less predictable or understood, and droughts and floods are increasing in intensity and frequency in some regions (see below).

Since 1901, temperatures in the northeast have risen from less than 0.6 °C (1 °F; West Virginia) to about 1.7 °C (3 °F; New England) depending on location and are expected to continue to rise (Dupigny-Giroux et al. 2018, p. 672). Total precipitation is expected to increase in the winter and spring, with little change in the summer. However, rainfall intensity has been increasing and is expected to continue (Dupigny-Giroux et al. 2018, p. 672).

In the Midwest, warm-season temperatures are projected to increase more than any other region of the United States (Angel et al. 2018, p. 880). The frost-free season is projected to increase from the historical period (1976 to 2005) by 20 days by midcentury (2036 to 2065), and possibly a month by late century (2070 to 2099) under a high emissions scenario (Angel et al. 2018, p. 880). Rainfall is expected to increase in the spring and flooding events are projected to increase in frequency. It is uncertain how often droughts will occur in the future (Angel et al. 2018, p. 880).

The climate in the southeastern United States has warmed about 1 °C (about 2 °F) from a cool period in the 1960s and 1970s and is expected to continue to rise (Carter et al. 2014, pp. 398–399). Inter-annual variability in precipitation has been increasing over the last several decades, with this region exhibiting either exceptionally wet or exceptionally dry summers (Groisman and Knight 2008, p. 1855; Wang et al. 2010, p. 1009). Extreme rainfall events (greater than 7.62 cm (3 in) in one day) are increasing (Carter et al. 2014, p. 399; Carter et al. 2018, p. 751). Projections suggest that overall annual precipitation will increase when available models are averaged (Figure 9), but individual models diverge in this region, with some showing a decrease in annual precipitation (Hegewisch et al. 2022, entire). The average number of days with an ambient temperature over 38 °C (100 °F) are projected to increase from fewer than 10 to between 10 and 30 days by mid-century and by more than 30 days by late-century under a high emissions climate scenario (Figure 8) (USFWS 2023, unpub. data). More Category 4 and 5 hurricanes are also expected occur (Carter et al. 2014, p. 399). Warmer temperatures and less predictable precipitation will increase water temperatures, change runoff regimes, and increase the frequency, duration, and intensity of droughts in the southeastern United States (Kunkel et al. 2013, p. 83; Poff et al. 2002, pp. ii–v), thus potentially reducing the availability of aquatic habitat available to spotted turtle populations.

Increased temperatures, changes in precipitation patterns, and sea level rise (SLR) resulting from climate change have the potential to affect the spotted turtle by altering habitat suitability within the species range, altering spotted turtle behavior and demography (sex ratios, mortality rates, reproductive success), and increasing their vulnerability to random catastrophic events (Willey et al. 2022, p. 147). Warming temperatures also have the potential to skew sex ratios, since spotted turtles have temperature-dependent sex determination (USFWS 2019, p. 1). Spotted turtles have been shown to lose their ability to right themselves at 42 °C (107 °F), which is considered their critical thermal maxima (Hutchinson et al. 1966, p. 38). In the southern extent of their range, spotted turtles are likely already at their maximum thermal tolerances; thus, even a small rise in temperatures in this region could impact activity (e.g., feeding, breeding) (Ward et al. 1976, p.

63; Yagi and Litzgus 2012, p. 187; Willey et al. 2022, p. 147), although exactly how spotted turtles will respond to these changes is unknown. Minimum temperature of the coldest month was the climate metric that best predicted current distribution of spotted turtle occurrences in an ensemble model by Willey et al. (2022, pp. 137, 140). Minimum January temperatures are projected to increase 2 to 2.5 °C (35.6 to 36.5 °F) for some spotted turtle sites under a moderate climate scenario and 4 to 4.5 °C (39.2 to 40.1 °F) under an extreme scenario by 2050 (Willey et al. 2022, p. 141). Under an extreme climate scenario, maximum July temperatures are expected to increase by 5.5 to 6 °C (41.9 to 42.8 °F) for states in the Mid-Atlantic through the Northeast by 2050, which is outside the range of current variation of these regions (Northeastern, Mid-Atlantic, and Southeastern regions) (Willey et al. 2022, pp. 142–144). Changes in rainfall patterns, with the addition of increased temperatures, can lead to the drying of wetlands (Ward et al. 1976, p. 63). When spotted turtle habitat experiences drying, there is also an increased risk of invasive species invasion or expansion, meaning additional management is required to remove or manage those invasive plants (Lipps 2023, pers. comm).

Further, SLR threatens coastal areas and many wetland habitat types and their distribution (Sweet et al. 2022, pp. 1–2; Dupigny-Giroux et a. 2018, p. 17). As sea level rises, higher elevations will become more frequently inundated, allowing for marsh migration landward. At the same time, some lower-lying areas will be so often inundated that the marshes will no longer be able to thrive, becoming lost to open water (NOAA 2023b, entire). These effects are already being seen, as pine forests are being lost to salinization in regions of Florida outside the spotted turtle range (Ross et al. 1994, entire; Drouin 2016, entire).

A SLR of one foot above current levels, which is probable by 2050, was estimated to impact 36 percent of coastal spotted turtle sites and 6 percent of potential habitat along the east coast of the U.S. (Willey et al. 2022, p. 8). By 2100 and 2 ft of rise, habitat loss at coastal sites could reach 11 percent. Loss is especially pronounced in the southeastern states, which could lose up to 20 percent of habitat by 2100 (Willey et al. 2022, p. 8).

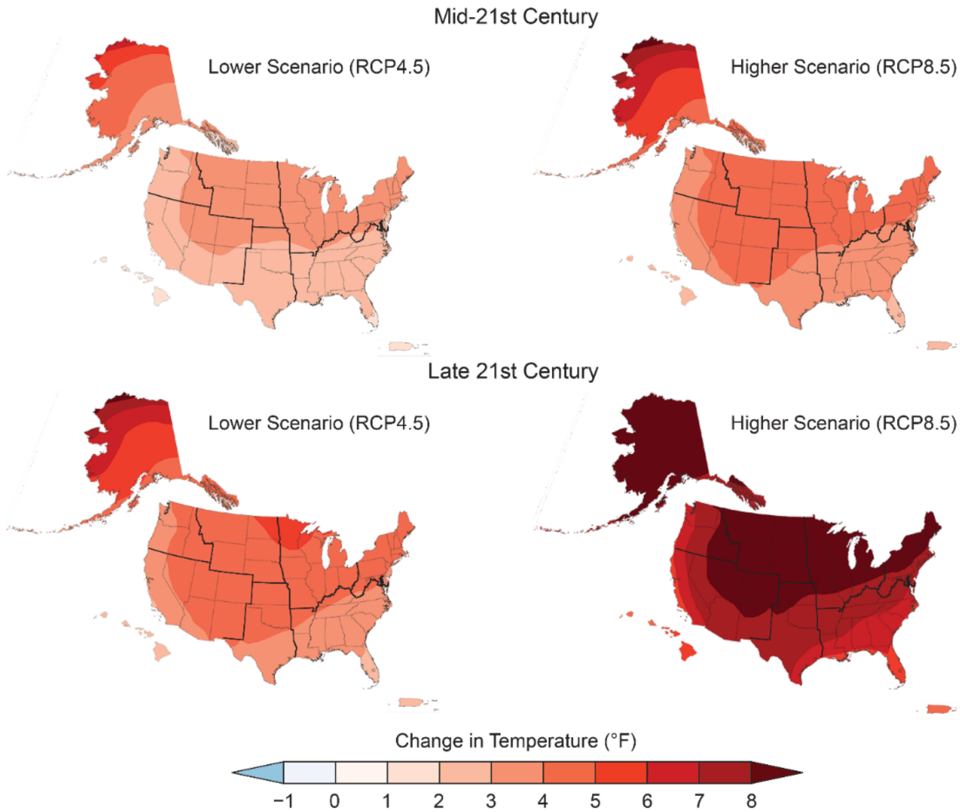

Figure 7. Projected increases in temperature by mid-century (2050) and late century (2100) under a lower and higher climate scenario. Figure from Hayhoe et al. 2018, p. 87.

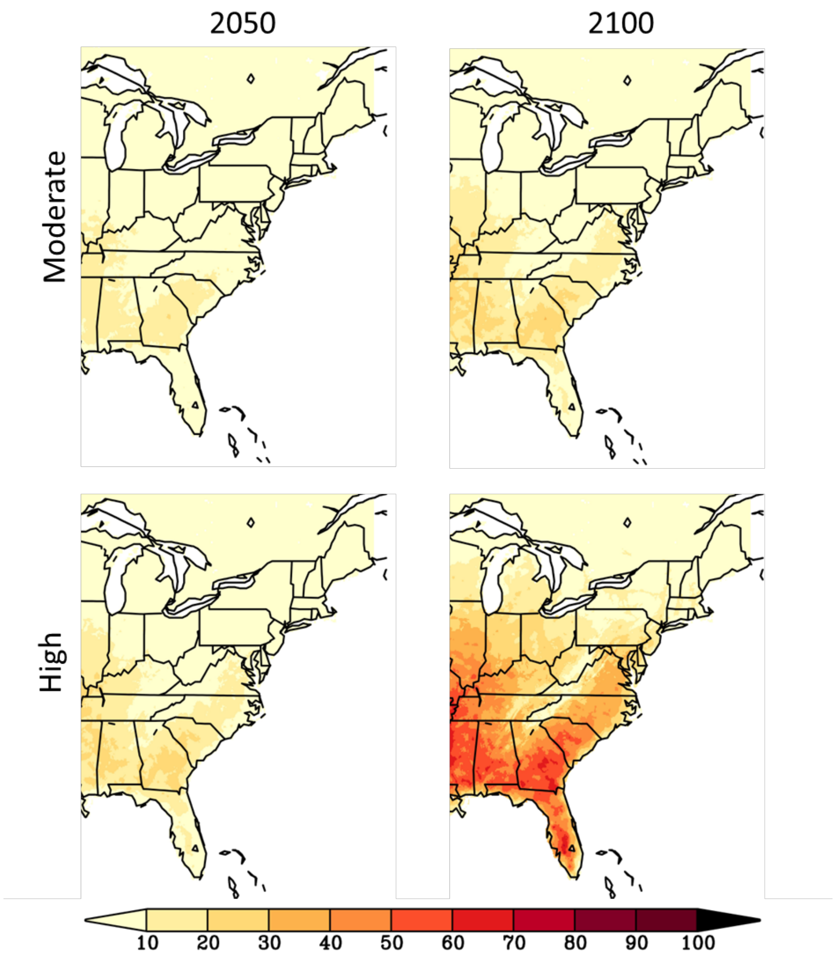

Figure 8. The number of days in which the temperature is projected to exceed 38 °C (100 °F) by mid (2050) and late (2100) this century, averaged across 32 model simulations, compared to less than 10 days currently for the entire spotted turtle range. Figure from the Localized Constructed Analogs (LOCA) dataset (LOCA 2023).

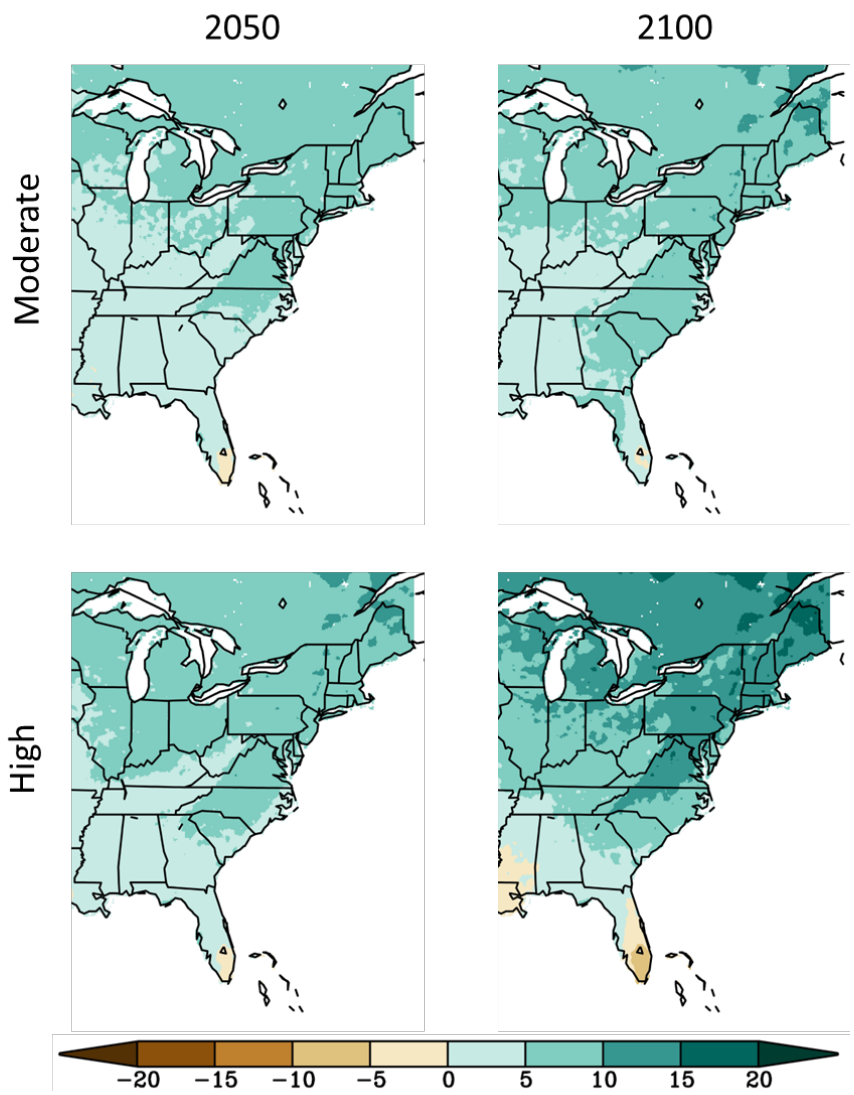

Figure 9. The percent change in total annual precipitation by mid (2050) and late (2100) this century from current for the spotted turtle range, averaged across 32 model simulations. Figure from the Localized Constructed Analogs (LOCA) dataset (LOCA 2023).

Changes in rainfall patterns may affect the favored wetland habitats of spotted turtles (USFWS 2019, p. 1). Increased rainfall and floods increase the potential for soil erosion, displaced turtles, decreased nest success, and habitat loss, and droughts can increase the spread of invasive species (Angel et al. 2018, p. 875). Drought can reduce the hydroperiod, or length of time that standing water exists on the landscape, and thus can affect the activity patterns of spotted turtles and lead to increased instances of dehydration or overheating (Willey et al. 2022, p. 147). In a study in Michigan, reduced late summer rainfall failed to replenish standing water and led to decreased spotted turtle activity and subsequently smaller home ranges and core area sizes compared to wetter years (Rowe et al. 2013, p. 97).

Climate change's impact to spotted turtle habitat has been examined in several studies. Most recently, Willey et al. (2022, pp. 7, 140) modeled climate suitability using occurrence records coupled with climate data and predicted a greater than 50 percent loss of suitable habitat by 2081 to 2100, with the coastal portion of the range seeing the most loss. The centroid of the distribution of suitable climate in this future timeframe shifts north from coastal Virginia to northern Pennsylvania under a moderate climate change scenario (469 km (291.42 mi) and to western New York (635 km (394.57 mi) under the high climate change scenario (Willey et al. 2022, pp. 140–141).

Another study within the northeastern U.S. determined that about half of the species' core habitat could be lost in the future due to climate (e.g., increased heat and drought events) (DeLuca 2021, p. 7). Using landscape suitability models, the highest-ranking habitat "cores" were examined to determine how these changed from current (2020) to future (2080) projection under a high emissions scenario (with no additional urban growth) (DeLuca 2021, entire). Approximately 50 percent of the cores present in 2020 (n = 1,761) were also present in 2080, representing climate refugia, and only 24 cores were added in 2080 (De Luca 2021, p. 7). Connectivity of these cores was also examined at both timesteps and the model revealed that spotted turtle habitat is already moderately disconnected, and connectivity is not projected to see a moderate decline due to the effects of climate change (De Luca 2021, p. 11). Given this species' limited mobility, facilitating connectivity among habitat cores will be important to allow generational movements and preserve metapopulation dynamics as species distributions shift due to climate change (De Luca 2021, p. 10).

Conservation practices can help alleviate some of the effects of climate change. For instance, restoring systems like wetlands and forested floodplains and increasing vegetative cover (e.g., cover crops and riparian buffers) can protect water quality and reduce flooding risks (Angel et al. 2018, p. 876).

Individual turtles may be able to alter their behavior to alleviate some of the effects of climate change, such as shifting timing of overwintering, mating, nesting, and aestivation to match changing temperature regimes, but given the long lifespan of this species, generational adaptation will not be fast enough (Willey et al. 2022, p. 147). There is some evidence of behavioral plasticity; turtles in cold climates often nest in dry, exposed soils, whereas those in hotter climates nest in wet or shaded areas (Willey et al. 2022, p. 147). However, given the spotted turtle's long generation time and limited dispersal ability, they have limited adaptive capacity (Appendix A).

In summary, the best available information suggests that climate change will alter conditions within most of the range of the spotted turtle by 2100 unless we dramatically reduce global emissions. However, the specific ways that these changes will affect spotted turtles is unknown and are likely to differ among areas within the range (Willey et al. 2022, p. 146). While we know there will be an effect on spotted turtles, how these effects manifest and the extent and severity of the realized impacts of climate change on spotted turtle populations are unknown. Given the longevity of the species, though, so long as temperatures do not exceed their thermal tolerance to survive, individuals may live for many years despite conditions being unsuitable for reproduction, causing the true effects of climate change to not be apparent or easy to observe for many decades (Willey et al. 2022, p. 147).

4.3 Disease, Parasites, and Predation

Disease is not currently known to be causing spotted turtle declines. Emydid herpesvirus 2 was found in a single spotted turtle in 2014 (Ossiboff et al. 2015, p. 1). It is unclear if or how this virus might affect spotted turtles, or how prevalent it is. *Emydomyces testavorans*, a fungus that causes ulcerative shell disease was also confirmed in several spotted turtles tested in North Carolina (Woodburn et al. 2019, p. 1). Observations of spotted turtles with some level of shell rot is common in North Carolina, but it is unknown whether the fungus is causing mortality (Hall 2023, pers. comm.). Climate change may increase the threat of disease and fungal infections in the future.

Leeches sometimes infest spotted turtles. For example, in Pennsylvania, 12 percent of spotted turtles, including 17 percent of adults, had leeches attached, typically to the limb sockets, tail, or plastron (Ernst 1976, pp. 31–32). Leeches were most prevalent in April through June (Ernst 1976, pp. 31–32). Leeches are unlikely to result in disease or mortality of spotted turtles.

Raccoons (*Procyon lotor*) are the most common predator of spotted turtles and their eggs (Ernst and Lovich 2009, p. 220). However, spotted turtles and their eggs are preyed on by a variety of animals, including snakes such as eastern ratsnakes (*Pantherophis obsoleta*) and watersnakes (*Nerodia sipedon*), birds such as crows (*Corvus* sp.), large wading birds, and bald eagles (*Haliaeetus leucocephalus*), fire ants (*Solenopsis invicta*), otters (*Lontra canadensis*), skunks (*Mephitis mephitis*), foxes (*Urocyon cinereoargenteus* and *Vulpes vulpes*), feral dogs (*Canis familiaris*), feral cats (*Felis catus*), muskrats (*Ondatra zibethicus*), small mammals, snapping turtles (*Chelydra serpentina*), and bullfrogs (*Lithobates catesbeianus*) (DeGraaf and Nein 2010, p. 667; Ernst and Lovich 2009, p. 220). In Pennsylvania, nearly 1 in 5 (17.9 percent) of adult spotted turtles had signs of injury due to predation attempts or mowers (the study did not separate these injuries), with raccoons as the primary suspected predator (Ernst 1976, p. 31). In Maryland and Delaware, Rocker (2021, p. 42) found that 10 percent of spotted turtles had tail or limb injuries, attributed to predators.

While natural predation events are expected and should not lead to population declines, introduced predators or those that occur near development and thus have easily available resources to support large populations may result in predation of spotted turtle eggs and juveniles, and likely reduce recruitment into existing populations (Meylan 2006, p. 231; Ernst and Lovich 2009, p. 220). Habitat fragmentation increases the ability for predators to reach spotted turtle nests, both at the large scale (more habitat edges mean more intrusion) and at the smaller scale (more woody shrubs within a fen create more dry pathways for access) (Lewis et al. 2004, p. 69). Predation (of both nests and adults) is listed as a major threat impacting population viability by seven states (Illinois, Michigan, Ohio, Massachusetts, Connecticut, Pennsylvania, and South Carolina) (USFWS 2023, unpublished data).

4.4 Collection

For spotted turtles, illegal collection from the wild was ranked at a 2020 Emydine Conservation Symposium as the second largest threat to the species by turtle conservationists (Meck 2020, p. 5). Skilled trapping can quickly wipe out local populations of spotted turtles, and opportunistic collection (often of females crossing roads) places an additional burden on the species (USFWS 2019, p. 1). Removal of adults from a population can substantially slow population growth due to the species' dependence on high adult survivorship (Enneson and Litzgus 2009, p. 1,252).

The species has been regularly available in commercial markets for at least 50 years (Connecticut Valley Biological Supply 1962; 1964 *In* Willey et al. 2022, p. 8), initially as a biological supply animal and eventually as a pet species. Early price data for the species suggests that it was relatively easy to collect from the wild, but later, the average real price per adult (adjusted for inflation) from 1998 to 2021 was 24.25 times the real price in 1962 to 1965, suggesting a regional decline in availability (or ease of collection) between 1965 and 1999, likely due to increased demand (Willey et al. 2022, pp. 8–9).

From 2011 through 2016, the U.S. estimates that turtle dealers exported more than 17 million wild-caught adults and "farmed" hatchling freshwater turtles (all U.S. native species), whose parents may have been wild-caught (CBD 2020, p. 2). Spotted turtles, likely captive-bred from wild-caught individuals, can be purchased easily as pets (Figure 10).

Figure 10. Spotted turtle babies for sale at a herpetological expo in San Antonio, Texas. While these are likely captive bred, at some point in their lineage, individuals were taken from the wild. Photo by Stephanie Martinez, Texas A&M NRI, used with permission.

From 1995 to 1999, 1,203 exports of spotted turtles were declared, and from 1999 to 2010, there were 727 export shipments totaling 7,881 individual spotted turtles; 16 percent of the exports were reported as wild (CITES 2013, pp. 5–8 ; Willey et al. 2022, pp. 26–27). The spotted turtle was added to Appendix II of CITES in 2013 (CITES 2013, pp. 1– 13; Willey et al. 2022, pp. 26–27). Appendix II includes species that could be threatened if trade of the species is not controlled. The CITES database contains 99 cases of legal spotted turtle imports and exports from 2013 to 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 U.S. exported 44 percent of these turtles and Hong Kong imported 92 percent of all traded turtles (Willey et al 2022, p. 9). Legal trade of captively bred individuals has continued, but illegal collection remains a concern. From 1998 to 2021, there were 54 state and Federal cases prosecuted and 24,000

North American freshwater turtles illegally caught, transported, or sold in these cases (Easter et al. 2023, pp. 766–767). Spotted turtles were the second most commonly reported turtle species associated with these cases (N = 17 cases; 694 individuals) (Easter et al. 2023, pp. 766–767). Illegal collection was reported by 11 states as a major factor affecting viability (Illinois, Michigan, Ohio, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Maryland, North Carolina, and South Carolina) (USFWS 2023, unpublished data). Commercial and personal collection of spotted turtles is illegal in 20 out of 22 states. However, one southern state allows commercial and personal collection while another southern state allows personal collection (Nanjappa and Conrad 2011, entire; Wixted 2023, pers. comm.).

Illegal and legal collection and trade of spotted turtles has occurred in the past, is occurring presently, and will likely continue to occur in the future. The magnitude of threat across the species range is considered a moderate- to high-level impact to the species as a whole.

4.5 Conservation, Restoration, and Management Efforts

Protection of habitat, specifically conservation of wetland complexes and the adjacent uplands, is often noted as a needed conservation measure, given this species dependence on both wetland and upland sites for various activities in its annual cycle (Chandler et al. 2019, p. 602; Joyal et al. 2001, p. 1755). In an analysis of delineated sites in the eastern U.S. (N = 2,351) where spotted turtles have been detected, approximately 28 percent of the total area within these sites region-wide has some level of protection and 15.1 percent of the sites are more than 50 percent protected (Willey et al. 2022, p. 7). Approximately 31 percent of all delineated habitat within current sites (detections from 1990 to 2021) is protected (Willey et al. 2022, p. 126). However, the level of protection or management of spotted turtles on these lands is unknown.

Protection of isolated habitats can still lead to local extirpations (Browne and Hecnar 2007, p. 427). For instance, spotted turtles are likely extirpated from Point Pelee National Park in Ontario, Canada, despite the area (16 sq km (9.94 mi)) being protected for over a century. Once the location of the greatest turtle species diversity in Canada, the turtle populations in the park declined, likely due to its isolation from other natural areas and the influence of populated areas surrounding it (Browne and Hecnar 2007, pp. 422–427).

Conservation efforts for spotted turtles are complicated by the species' low annual reproductive output, late maturity, and long generation time, meaning that population responses to any management actions will be slow. It could take years to decades before meaningful changes can be detected, which necessitates long-term research and monitoring.

Management Efforts

There is evidence that spotted turtles will quickly use artificial nest sites, which could promote reproduction in areas where existing sites are limited. Further, strategically establishing artificial nest sites during the nesting season could reduce adult females' upland excursions, decreasing the chances of road or other mortality of adults and hatchlings (Beaudry et al. 2010, p. 1).

A stage-classified matrix used with a long-term (30 year) dataset from a population in Ontario found that nest protection and headstarting are insufficient conservation strategies for the spotted turtle, and that small increases to adult survivorship and increasing juvenile survivorship to 100 percent had the largest effects on the population growth rate, indicating that adults and juveniles should be targeted for conservation (Enneson and Litzgus 2008, p. 1560).

State Conservation Programs

A conservation plan was developed by the eastern states (from Maine to Florida) in 2022, funded by a CSWG (Willey et al. 2022, entire). The plan is a product of a multi-year, proactive effort among state wildlife agencies and their partners to articulate a strategic action plan to protect populations of spotted turtles throughout the eastern part of their range. The plan is composed of: (1) site delineation and a habitat suitability model; (2) an empirical population assessment (using information from standardized surveys); (3) an evaluation of habitat loss and future projections of loss due to climate change; (4) a spatially-explicit, empirically-derived regional Conservation Area Network; (5) a multi-scale Conservation Action Plan for focal core areas; and (6) technical assistance materials (appendices) for partners and key landowners.

Michigan and Ohio are in the third year of implementing a CSWG for spotted turtle to determine status and distribution, assess genetic population structure and effective size, identify high priority sites to implement adaptive conservation and management actions, and initiate implementation of these efforts (Cross 2023, pers. comm.).

Vermont also received a CSWG in 2022 to identify suitable spotted turtle habitats, support the development of eDNA sampling protocols, use standardized methods to evaluate turtle presence, and improve priority nesting habitat.

Most recently, another CSWG was awarded in 2023 to West Virginia, Virginia, North Carolina, South Carolina, Georgia, and Florida to improve knowledge of the status of the species in the southeastern U.S. Standardized surveys and genetic analysis will be used to develop an expanded Conservation Area Network. Two years of surveys at a focal site in each state will also be used to perform population assessment and viability analyses. A rigorous population analysis will be used to evaluate threats on populations in the southeast to help inform conservation planning. Other key activities include testing additional survey methods and comparing detection rates to the standardized monitoring developed for the first eastern U.S. CSWG; providing technical assistance to landowners and land managers and other relevant state and Federal agency partners to update regulations, protect sites through purchase, easement, or change in use, or undertake habitat management in key areas; restoring, enhancing, creating or managing 87 ha (215 ac) by December 2026; planning, hosting, and participating in an illegal trade workshop and engaging with law enforcement in all six states; and revising the Conservation Plan developed under the first CSWG with the information obtained during this project (GA DNR 2023, entire).

Conservation Efforts on Federal Lands

Spotted turtles are found on U.S. Fish and Wildlife Service Refuges, National Parks, U.S. Forest Service land and Department of Defense military installations. There have been survey, research, and conservation efforts implemented by these land managers for spotted turtle across the range. Other notable conservation efforts include the Natural Resource Conservation Service's (NRCS) Working Lands for Wildlife Northeast Turtles Program and incorporation of spotted turtle into military installation's Integrated Natural Resource Management Plans.

A Working Lands for Wildlife Northeast Turtles Program was established by the NRCS in 2016 for landowners in Connecticut, Massachusetts, Maine, New Hampshire, New York, Rhode Island, and Vermont. The program provides technical support through NRCS, the states, and other partners (including the Service) to help private landowners, including farmers, conserve turtle species through easements, restoration, and habitat management. In Rhode Island, a 143.7-ha (355-ac) Wetland Reserve Easement was identified as potential habitat for spotted turtle, and spotted turtle was identified as a species that would benefit from the easement and planned restoration work (Hayden 2023, pers. comm.). Massachusetts has made the most progress in implementing projects for spotted turtle, and as an example of what could be accomplished in the States, Massachusetts has completed the following to date (**Error! Reference source not found.**) (Magee 2023, pers. comm).

Table 3. Conservation practices implemented or planned for spotted turtle in MA.

Practices Applied & Planned 2023	Tagged for Spotted Turtles (no. or acres)	Tagged for Spotted Turtles (no. or acres)
	APPLIED status	PLANNED status
Access Control (472)	8.7 ac (3.52 ha)	5 ac (2.02 ha)
Brush Management (314)	187.5 ac (75.88 ha)	1061.1 ac (429.4 ha)
Conservation Cover (327)		10.9 ac (4.4 ha)
Early Successional Habitat Development (647)	211.8 ac (85.71 ha)	295.4 ac (119.54 ha)
Fencing (382)		31,174 LF (9.50 km)
Forest Management Plan (106)		1 no.
Herbaceous Weed Treatment (315)	7 ac (2.83 ha)	5.1 ac (2.06 ha)
Stream Habitat Improvement and Management (395)		2.9 ac (1.17 ha)
Forest Stand Improvement (666)	44.4 ac (17.96 ha)	379.1 ac (153.41 ha)
Wetland Wildlife Habitat Management (644)	14.6 ac (5.91 ha)	696.1 ac (281.70 ha)
Tree/Shrub Establishment (612)	5 ac (2.02 ha)	8.1 ac (3.28 ha)
Restoration of Rare or Declining Natural Communities (643)	352.9 ac (142.81 ha)	469.9 ac (190.16 ha)
Upland Wildlife Habitat Management (645)	425.4 ac (172.15 ha)	92.8 ac (37.55 ha)

Department of Defense-Integrated Natural Resource Management Plans

The U.S. Department of Defense (DoD) developed a best management practices (BMPs) document with the U.S. Fish and Wildlife Service for spotted turtles that occur on its military installations. These 16 BMPs include habitat identification and surveys and various practices to aide in the protection and management of habitat, such as invasive species removal and control of subsidized predator populations (DoD PARC 2019, pp. 6–7). Spotted turtles are confirmed to be present on 40 military sites within the species range (DoD PARC 2019, pp. 3–4), but the species is specifically mentioned in the Integrated Natural Resources Management Plans (INRMPs) of 22 military installations (Table 4). Nineteen of these survey for the species, while 11 conduct habitat management specific to the species. Two installations mention habitat creation, and two mention that they follow the BMPs created for spotted turtle (Table 4) (DoD PARC 2019, entire).

Table 4. Military installations and their location that list the spotted turtle in their Integrated Natural Resources Management Plans (INRMP), including the specific practices carried out on the installations (e.g., surveys, habitat management, and any other management strategies listed).

Branch	Base	State	Surveys	Hab. Mgmt	Other	Citation
Air Force	New Boston AFS	NH	Y	Y	Mark-recapture	USDOD 2020d, p. 43
Air Force	Otis Air National Guard	MA		Y	Unclear	USDOD 2020e, p. 35
Army	Devens Reserve Forces Training Area	MA	Y	Y	Education	USDOD 2019a, p. 37
Air Force	Westover Air Reserve Base	MA			Unclear	USDOD 2020f, p. 28
Army	Fort Drum	NY	Y			USDOD 2021b, p. 119
Army	West Point Military Reservation	NY	Y	Y		USDOD 2018b, p. 4.49
Army	Fort Indiantown Gap	PA	Y	Y	BMPs	USDOD 2021c, p. B.11
Army	Letterkenny Army Depot	PA	Y			USDOD 2019c, p. B.37
Air Force	Joint Base McGuire-Dix-Lakehurst	NJ	Y	Y	BMPs	USDOD 2020a, p. 161
Air Force	Warren Grove Air National Guard	NJ	Y			USDOD 2018c, p. 5.10
Army	Picatinny Arsenal	NJ			Unclear	USDOD 2022, p. 82
Army	New Castle River Road Training Site	DE	Y			USDOD 2020c, p. 32
Army	Aberdeen Proving Ground	MD	Y			USDOD 2021a, p. 4.37
Navy	NSF Indian Head	MD	Y	Y	Habitat enhancement, creation	USDOD 2019e, p. 4.33
Air Force	Joint Base Langley-Eustis	VA	Y			USDOD 2019b, p. 48
Army	Fort Belvoir	VA	Y	Y	Mark-recapture	USDOD 2018a, p. 8.12
Army	Fort Lee	VA	Y		Mark-recapture	USDOD 2020b, p. 43
Army	Maneuver Training Center-Fort Pickett	VA	Y	Y		USDOD 2021d, p. 3.15
Navy	Naval Support Facility Dahlgren	VA	Y	Y	Habitat enhancement, creation	USDOD 2021e, p. 3.24
Navy	NALF Fentress	VA	Y	Y	Invasive removal, water quality improvement	USDOD 2019d, p. 1711
Marine Corps	MCB Camp Lejeune	NC	Y			USDOD 2014, p. 4.122
Marine Corps	MCAS Beaufort	SC	Y			USDOD 2013, pp. 3.15-3.19
Army	Fort Stewart	GA			Unclear	USDOD 2012, p. 224
Air Force	Cape Canaveral AFS	FL			Unclear	USDOD 2020g, p. 672
Count	22		7	4		

4.6 Summary

Habitat loss, degradation, and fragmentation, both historical and ongoing, are the largest and most often cited threats to the viability of the spotted turtle (Figure 11). Habitat impacts can occur primarily through human land use changes and climate change. Land use changes, specifically additional development, can increase the likelihood of some of the other biggest threats to the species; for instance, more roads increase the risk of road mortality and additional access to sites increases the risk of illegal collection. Human developments can often attract and subsidize mesopredators, which can increase predation of nests, juveniles, and adults. Development can also increase invasive plant species which can alter wetland hydrology (Oxenrider 2023, pers. comm.).

Due to the long generation time of the species, any additive adult mortality—due to collection, roads, predation, or other impacts—can have a significant impact on populations of spotted turtles. Detailed demographic studies are necessary and are being conducted by the states and researchers to detect potential declines in specific populations of spotted turtle. Populations may already be undergoing declines in viability that are not yet apparent due to their longevity.

Impacts to spotted turtles due to land use change and climate change is further explored and carried forward in the future condition analyses, Section 6 below.

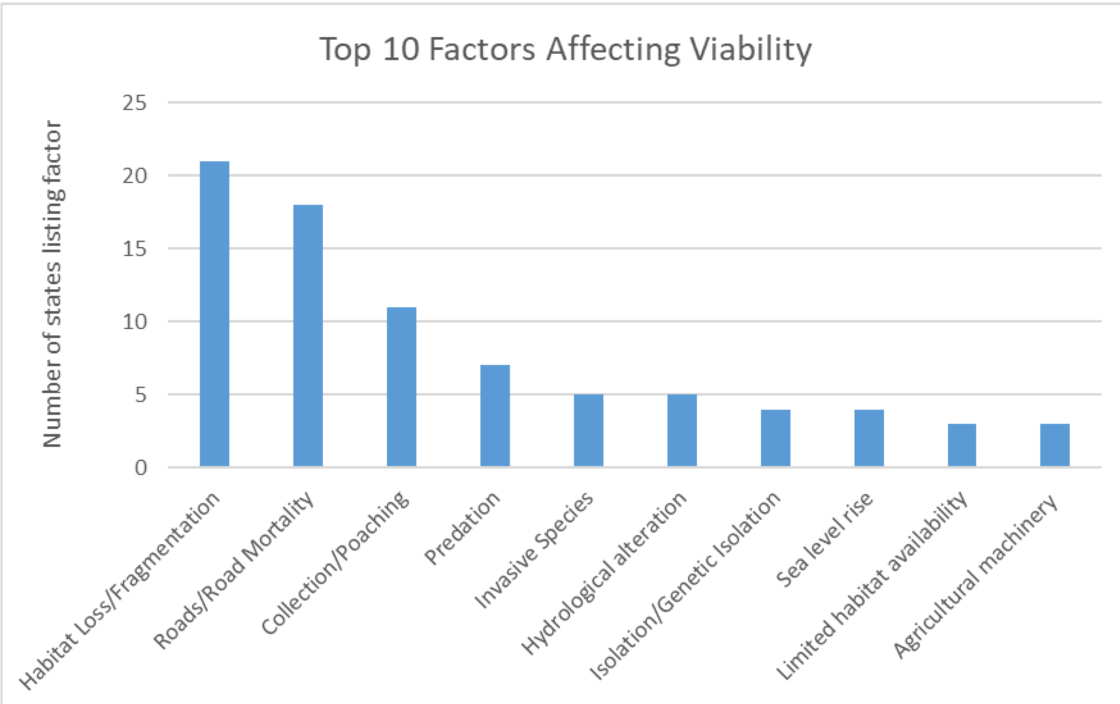

Figure 11. In a data request to the 21 states within the spotted turtle range (see Section 5.1), states were asked to note the major factors affecting viability in their state. Of the top 10 factors mentioned by the states, 9 (excluding sea level rise) can be traced to development and agriculture.

5 CURRENT CONDITION

In this section, we outline our methodology and then characterize the overall current condition of the spotted turtle in terms of resiliency and species' representation and redundancy (the 3Rs).

5.1 Methodology

Special Considerations

Spatial data for the spotted turtle is sensitive in nature due to the threat of illegal collection and is therefore not openly shared. Due to the risk of data being requested via the Freedom of Information Act (FOIA), we and our state partners determined that the safest course of action was for us to not obtain spatial data from the states. Instead, we worked with our state partners, land managers, and species experts to request data that was summarized at a larger spatial area that made sense for the species, using EPA Level III Ecoregions (see Analysis Units, below).

To determine the current condition for the spotted turtle, we first reviewed the literature to determine what factors would be important to consider in our analysis. We worked with species experts across the range to develop a table that summarizes relevant information for each state within each defined analysis unit.

To further obscure location data, some results are summarized for inclusion in this SSA document, although resiliency is assessed on a more local (analysis unit) level to obtain a full picture of spotted turtle status. Species viability will be assessed using analysis unit level data.

Analysis Units

Resiliency is typically measured at the population level. However, there is not a standard definition for a population or subpopulation of spotted turtles. Therefore, we divided the species range into ecological units to assess resilience. We selected the EPA Level III (L3) Ecoregions as analysis units for this species, further divided by state boundaries (Figure 12). Because spotted turtles exist in wetlands that vary in their type, vegetation, and other ecological factors based on location, we propose that habitats likely are more similar within rather than among ecoregions, and habitats within an ecoregion can likely be managed in similar ways. These units are not meant to represent "populations" in a biological sense; rather, these units were designed to subdivide the species range in a way that facilitates assessing and reporting the variation in current and future resilience across the range. Using these ecoregions also provides a standardized way to define analysis units and summarize differences in species and habitat conditions across an extensive range and from data collected at multiple different scales and using different methodologies.

For mapping purposes, we portray the range of the spotted turtle using a range map (see Figure 2) developed in collaboration with our state partners. This map is meant to portray the range generally; not all areas within this polygon are occupied. States then indicated which L3 ecoregions are occupied and these are portrayed on the map, clipped to the range map outline (Figure 12). Thus, not all areas within all L3 ecoregions are occupied.

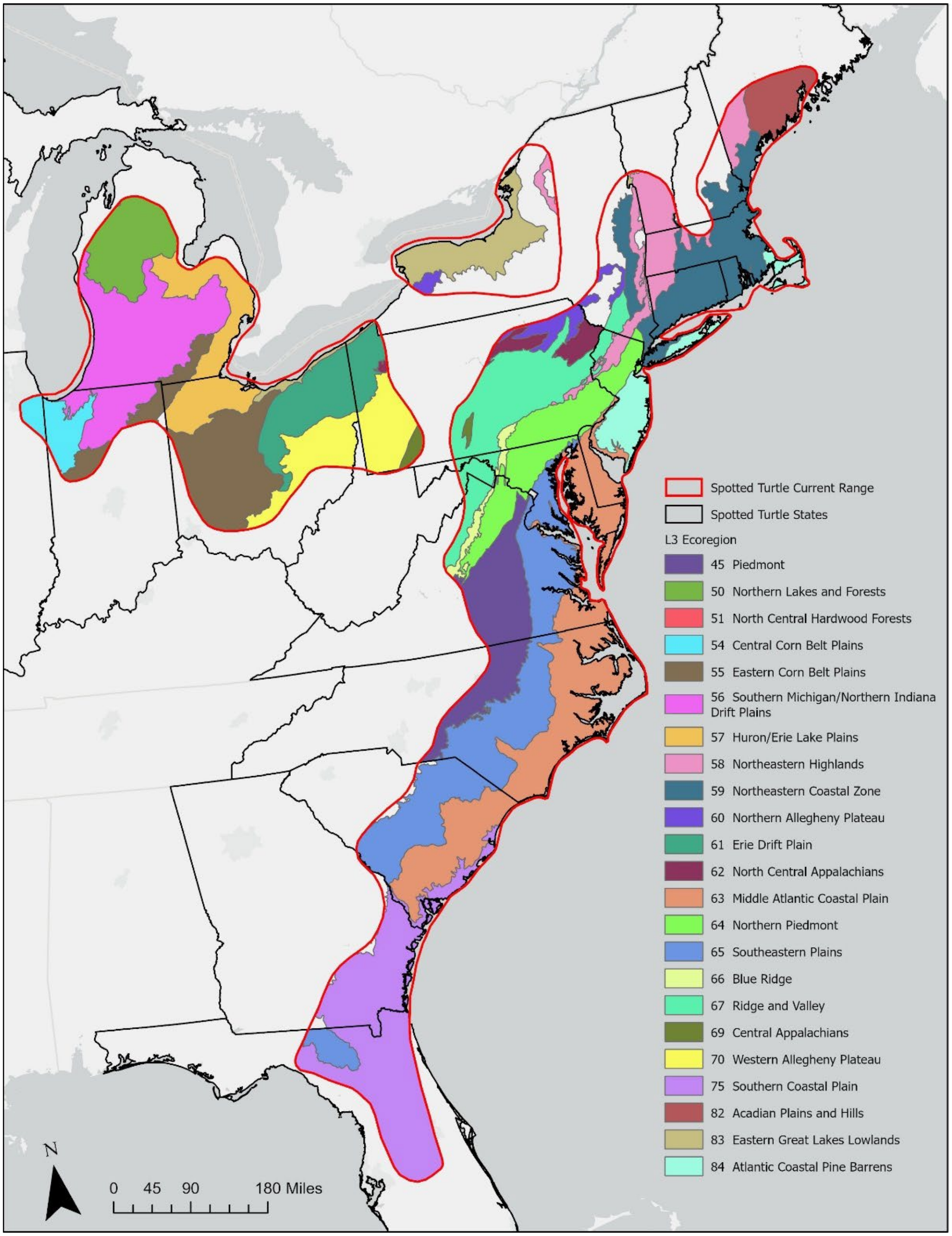

Figure 12. Spotted turtle analysis units, using L3 Ecoregions and state boundaries within the defined range of the spotted turtle.

Species representation refers to the extent of genetic and environmental diversity within and among populations (or, in this case, analysis units) that contribute to the ability of the species to respond and adapt to changing environmental conditions over time. There is currently no evidence of subspecies or "types" of spotted turtle based on genetic analysis (Dyer and Whitehurst 2023, entire); however, habitats, and therefore likely life history parameters, vary by ecoregion. Given this species' large range, we use Level II (L2) Ecoregions as a proxy for representation units. Further, while spotted turtles likely have adaptive capacity given the various landscapes and physiographic regions they occur in, the ability to adapt quickly enough to changing conditions is likely limited due to the species' long generation time.

Because these analysis units are different sizes, we use "area-weighted" percentages instead of raw counts of analysis units when presenting the results of our various analyses. While counts of the number of analysis units are also sometimes provided, we present results as the percent of the range by area using the sum of the area of the analysis units.

Resiliency

We assessed the current condition of spotted turtle populations in each analysis unit to gauge the relative ability of each unit to withstand stochastic events (resiliency). We requested summary information from each state for each of these analysis units within the range of the spotted turtle; this provided a common spatial reference that could be used by all states. Using the ecoregions also allowed us to provide a data analysis at a level to ensure that population data is obscured in this report. Each state provided summary data for the portions of each L3 ecoregion that occurs in their state; ecoregions that fall within multiple states are analyzed separately and count as separate analysis units.

Current records are those recorded within the past 30 years (1991 to 2021). This is a conservative approach based on feedback from the experts that takes into consideration the average age and generation time of the species. Responses for habitat availability, spotted turtle density within available habitats, and the population trajectory for each analysis unit were standardized using a dropdown in the excel spreadsheet, meaning that only a certain range of responses was allowed (Table 5). We also standardized the response for how confident the state was in their assessment of the current condition for that analysis unit (i.e., low, medium, or high confidence).

Table 5. Allowed responses for habitat availability within the analysis unit, turtle density within occupied habitats (and connectivity of those occupied habitats), and trajectory for each analysis unit.

Habitat Availability and Connectivity Within Analysis Unit
Abundant, widespread, connected
Abundant and widespread but isolated
Somewhat abundant and widespread with some connectivity
Uncommon with some connectivity
Uncommon, isolated

Spotted Turtle Density Within Habitats
Individuals abundant and widespread with habitat connectivity
Individuals abundant and widespread but highly fragmented
Individuals somewhat abundant and widespread with some habitat connectivity
Individuals uncommon with restricted occurrence and some connectivity
Individuals uncommon with restricted occurrence and highly fragmented
Population Trajectory Within Analysis Unit
Increasing
Stable
Varies
Unknown
Decreasing

In addition to these fields, we also requested data for each analysis unit regarding the wetland types (including the two that were most common) used by spotted turtles, major factors affecting viability, existing conservation measures, and conservation measures that are needed. Additionally, we included optional fields for the number of element occurrences or habitats known to be occupied within each analysis unit, the number that were historically occupied but now considered extirpated, and a total population estimate.

Once data tables were received from the states, the data was combined into a master spreadsheet for analysis. We based the current condition of each analysis unit on the habitat availability, population density, and population trajectory values. We first assigned each analysis unit an "abundance score" based on the habitat availability and population density in those habitats, as shown in Table 6. Values are slightly more aligned with population density than with habitat availability; while less habitat availability will have some effect on resiliency, we assume the abundance of individuals in the available habitat is more indicative of resiliency, as the species has existed in naturally fragmented habitats (such as ephemeral wetlands) throughout its evolutionary history. We then considered the population trajectory response alongside this abundance score to assign a resiliency rating for each analysis unit (Table 7). Note that a "stable" trajectory can shift the abundance score up to a higher resiliency rating, and only those analysis units that were given a "decreasing" trajectory are given a "low" resiliency rating. Because spotted turtles have persisted in areas away from the coastal plain where habitat is naturally uncommon and isolated, we hypothesize even sparse populations can be moderately resilient.

States were given the opportunity to review the responses across the range and the resulting resiliency rating categories, discuss with neighboring states any discrepancies, and make any adjustments to their responses.

While this resiliency rating is based on the perceived current habitat availability, population density within occupied habitats and connectivity of those occupied habitats, and population trajectory, these ratings are a proxy for true population resiliency and should be considered relative to one another. A resiliency rating of high can be assumed to have higher resiliency than a resiliency rating of moderate, but a high resiliency rating does not necessarily indicate that that analysis unit is highly resilient.

Table 6. Abundance scores based on the population density in and connectivity of occupied habitats and the habitat availability and connectivity of habitat available within each analysis unit as reported by each state. Abundance scores are weighted towards the population density.

	Habitat available				
Population density in occupied habitats:	Abundant, widespread, connected	Abundant and widespread but isolated	Somewhat abundant and widespread with some connectivity	Uncommon with some connectivity	Uncommon, isolated
Individuals abundant and widespread with habitat connectivity	High	High	High	High	Moderate
Individuals abundant and widespread but highly fragmented	High	High	High	Moderate	Moderate
Individuals somewhat abundant and widespread with some habitat connectivity	High	Moderate	Moderate	Moderate	Low
Individuals uncommon with restricted occurrence and some connectivity	Moderate	Moderate	Low	Low	Low
Individuals uncommon with restricted occurrence and highly fragmented	Low	Low	Low	Low	Low

Table 7. Resiliency rating assignments, based on the Abundance Score (Table 6) and population trajectory, as reported by each state. Resiliency ratings should be considered relative and a proxy for true population resiliency.

	Trajectory			
Abundance Score	**Stable**	**Varies**	**Unknown**	**Decreasing**
High	High	High	High	Moderate
Moderate	High	Moderate	Moderate	Low
Low	Moderate	Moderate	Moderate	Low

Current Landscape Condition

In addition to assessing the current condition of the spotted turtle using demographic factors based on polls and expert knowledge, we also assessed broad-scale landscape condition within each analysis unit. While population factors like population density and trajectory indicate how each population is doing given the current existing threats and other habitat conditions, we selected additional landscape factors, including landcover types, to better understand the general landscape condition (such as the potential amount of habitat available in each analysis unit) and to compare landscape metrics to expert knowledge of the species' condition. Further, threats from human land uses, such as development or agriculture, are likely to continue or change over time; thus, this analysis provides a baseline for landscape composition to which we can apply our future condition scenarios.

We do not include landscape condition in our resiliency assessment. Information received from our state partners about the status of each population in terms of demographic data is more indicative of resiliency than availability of habitat, and information regarding connectivity of populations (occupied habitat) was included in the information received from our state partners. However, we use landscape condition to provide additional context of overall analysis unit suitability.

While we are unable to assess habitat factors and habitat suitability at a local scale, we focus on general land use categories at a landscape scale to provide a large-scale assessment of general land uses (forest, development, agriculture, etc.) within the range of potential habitat.

Landscape Metrics

Using the National Land Cover Dataset (NLCD) (NCLD 2019, dataset), we quantified the percentages of different landcover types within each analysis unit. The NLCD categorizes land uses at a 30-m (98-ft) scale as of 2019 (NCLD 2019). To simplify the land cover types, we grouped various categories, yielding "forested" (deciduous forest, evergreen forest, and mixed forest categories), "developed" (developed open space, low intensity, medium intensity, and high intensity development categories), "agriculture" (hay/pasture and cropland categories), and "wetlands" (woody wetland and emergent herbaceous wetland categories).

We also compared these landcover types to our resiliency rating metric to determine how or if these landcover types are related to spotted turtle resiliency.

5.2 Results

We received data from all 21 states within the range of the spotted turtle, within 7 L2 Ecoregions and 23 L3 ecoregions, for a total of 79 analysis units. Optional data indicating the numbers of element occurrences and estimated population sizes were not supplied by all states and data was not standardized, so this information was not included in the analyses.

By area, 47 percent of the analysis units have an unknown trajectory, while 18 percent of the range has a decreasing trajectory (Table 8). No analysis units have an increasing trajectory.

Table 8. Percentage of the total range of the spotted turtle that was assigned each ranking for the population trajectory within the analysis unit.

Trajectory	Percent Total Range
Increasing	0%
Stable	11%
Varies	24%
Unknown	47%
Decreasing	18%

Range wide by area, spotted turtle habitat within most of the analysis units (47 percent) is somewhat abundant and widespread with some connectivity (Table 9). Thirteen percent of the range harbors abundant and widespread habitat (both connected and isolated), while 22 percent contains habitat that is uncommon and isolated (Table 9).

Table 9. Percentage of the total range of the spotted turtle that was assigned each ranking for the habitat availability within the analysis unit.

Habitat Availability Within Analysis Unit	Percent Total Range
Abundant, widespread, connected	7%
Abundant and widespread but isolated	5%
Somewhat abundant and widespread with some connectivity	47%
Uncommon with some connectivity	19%
Uncommon, isolated	22%

Analysis units that had a high abundance score, using the habitat availability and population density scores as shown in Table 6, were located along the east coast, while the low abundance scores are mostly in the interior of the region (Figure 13). This is in line with our assumptions about where the species has been naturally more abundant due to habitat availability.

Current Resiliency

Range wide, 11 percent of the total range is classified as having a high resiliency rating, while 17 percent of the range has a low resiliency rating; the remaining 72 percent has a moderate resiliency rating (Table 10).

Table 10. Percentage of the total range of the spotted turtle ranked as each resiliency category.

Resiliency	Percent Total Range
High	11%
Moderate	72%
Low	17%

Most of the analysis units with a high resiliency rating are located along the Atlantic coast, mostly within the Southeast USA Coastal Plain Level II ecoregion (Figure 2, Figure 14). Areas that have a low resiliency rating are spread throughout the range of the species (Figure 14).

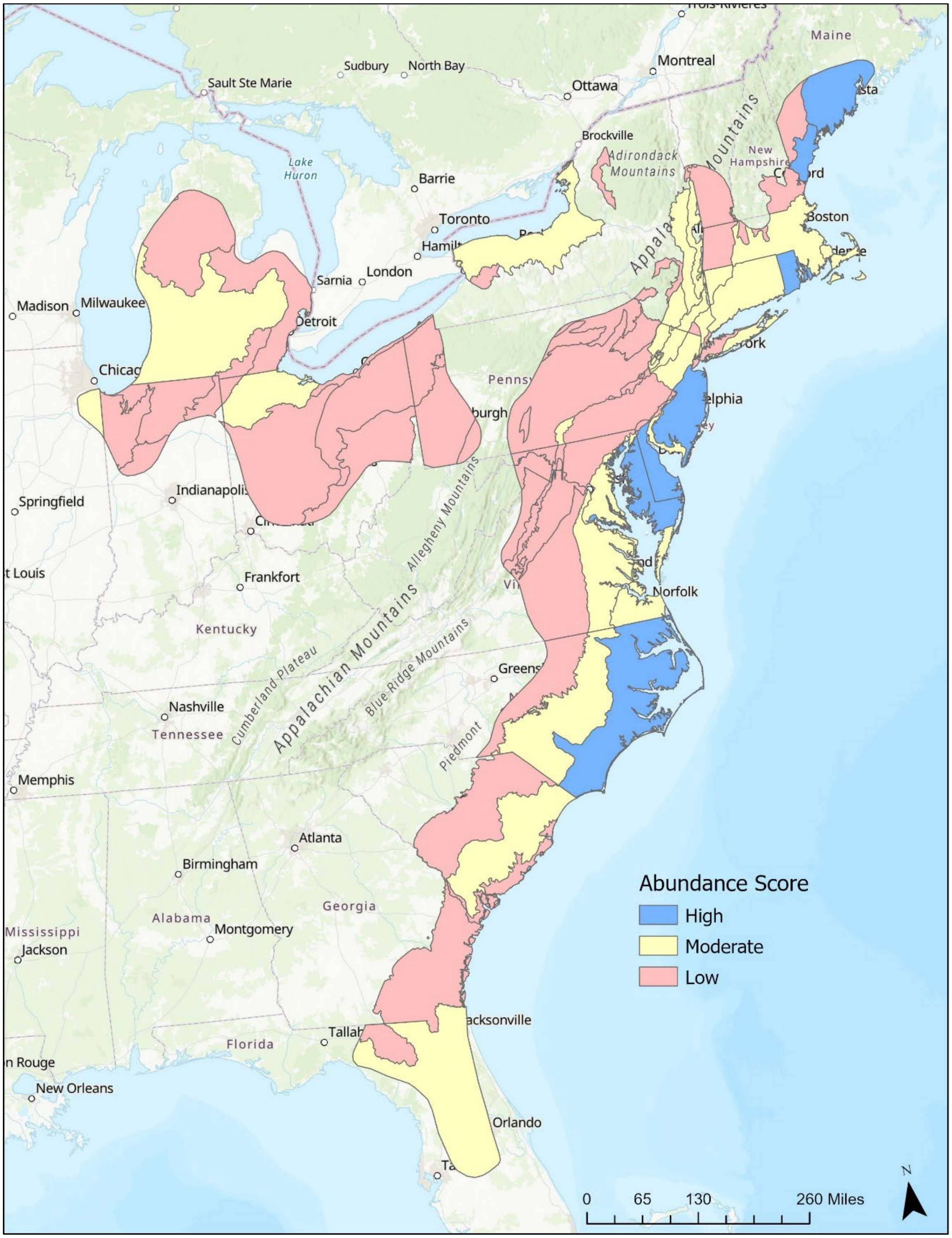

Figure 13. Abundance scores based on state responses to habitat availability and population density, based on Table 6.

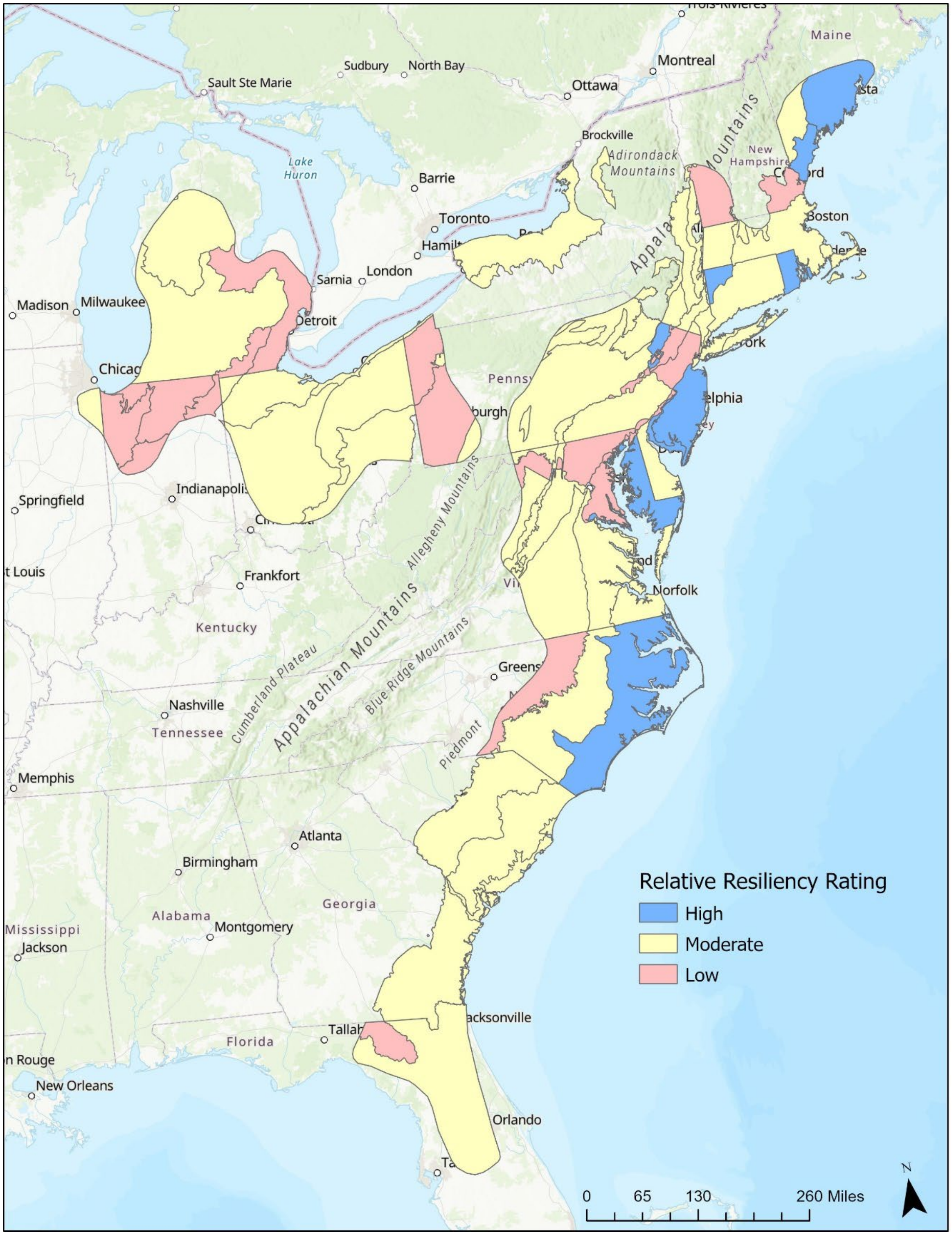

Figure 14. Resiliency rating of each analysis unit following methodologies outlined in Section 5.1.

Current Landscape Condition

Looking at landscape cover differences by L2 Ecoregion (see Figure 2), wetland cover is highest in the Coastal Plains and lowest in the Appalachian Forests (Figure 16). Wetland cover is generally the same in the Mixed Wood Plains, Central Plains, and SE Plains. Development is highest in the SE USA Plains, which includes the land between the Coastal Plains and Appalachian Forests, ranging from the mid-Atlantic to the south. The Coastal Plains has the second highest amount of development but more wetlands than the SE Plains. Forested land use is highest in the Appalachian Forests and Atlantic Highlands (Figure 16).

Comparing these landscape metrics to resiliency range wide, we found that areas with low resiliency also generally had low percentages of wetlands, while areas with high resiliency generally had low percentages of development in the analysis unit (Figure 15).

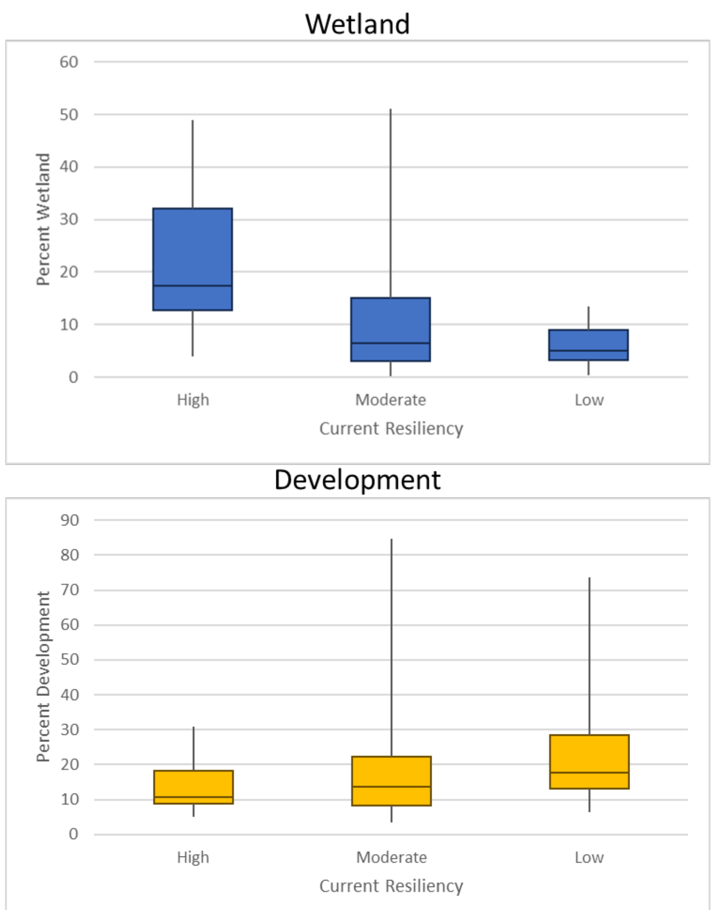

Figure 15. Percentage of each analysis unit comprised of wetlands (top) and developed areas (bottom) by the resiliency ranking of that analysis unit.

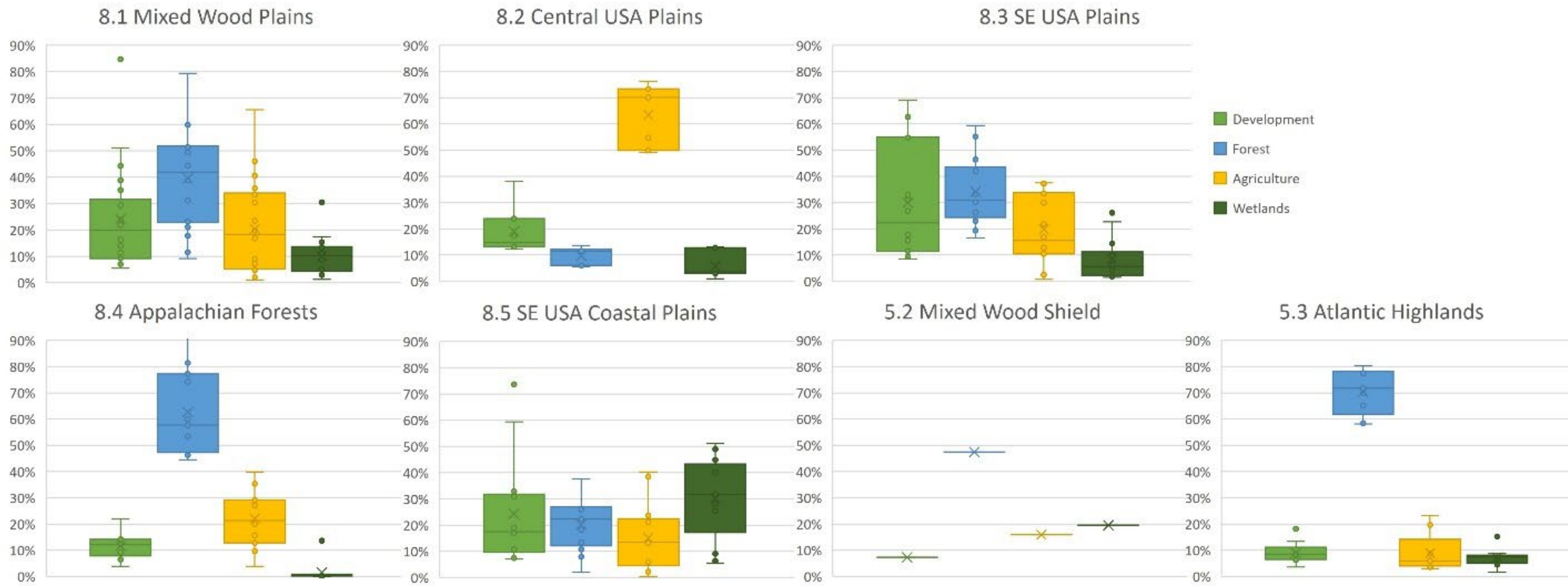

Figure 16. Landcover types by L2 Ecoregion within the range of the spotted turtle. Ecoregions are mapped in Figure 2.

5.3 Current Redundancy and Representation

Species representation refers to the extent of genetic and environmental diversity within and among populations (or, in this case, analysis units) that contribute to the ability of the species to respond and adapt to changing environmental conditions over time. There is no evidence of subspecies or "types" of spotted turtle based on genetic analysis. Given the various wetland types and ecoregions the spotted turtle occurs in, the species is assumed to have some amount of adaptive capacity to persist under a broad range of conditions, although there are limitations, especially given its long generational time.

Given the large range of the spotted turtle and its presence in 79 analysis units within 21 states and 7 L2 ecoregions, the species currently has many populations and therefore high redundancy compared to species with narrower ranges.

5.4 Uncertainties

Knowledge gaps in our understanding of spotted turtle populations and their habitat, as well as our analysis methodologies and their limitations, provide several areas of uncertainty that could lead to inaccurate estimates of current resiliency.

First, this species has knowledge gaps due to its large range and variation in habitat types, leading to limitations, including:

- There is no consistent definition of what constitutes a population or subpopulation across the range. This could lead to over- or under- estimates of resiliency.
- Numbers of adult, juvenile, and hatchling turtles are unknown at many sites. This could lead to inaccurate estimates of resiliency.
- Species demographics and viability are spatially variable at a fine scale (potentially on a site-by-site basis). This could lead to over- or under- estimates of resiliency.
- It is very likely that not all existing populations/sites have been surveyed. This could lead to underestimation of resiliency in some analysis units, as well as underestimation of overall species redundancy and representation.

Also, the methods used in our analyses provide additional uncertainties, including:

- With the spreadsheet analysis, there may be variability in the way the states interpreted and responded to the table, depending on their comfort and understanding of their data. How individual states interpret abundant versus uncommon, or connected versus fragmented, may vary by state. States were encouraged to discuss variation in their responses with neighboring states to address some of this uncertainty.

- Spotted turtle condition may vary across an L3 ecoregion; while ecoregions were separated by state boundaries, allowing for this variation to be captured, those that crossed more states can have more variation than those in that crossed fewer states. This could lead to inconsistent estimates of resiliency among analysis units.
- The trajectory of the species is unknown for most analysis units. Currently, 11 percent of the range is classified as having high resiliency; if all the unknowns are stable, that increases to 24 percent of the range, and if all the unknowns are actually decreasing, this does not change. Likewise, if the unknowns are actually all decreasing, the percent of the range ranked as high resiliency does not change, but 64 percent of the range would be classified as low resiliency as opposed to 17 percent, currently (Table 11). Thus, while this could lead to over- or under-estimates of resiliency, it is more likely that resiliency is being over-estimated in much of the range.
- In analysis units where low confidence was reported due to lack of survey effort, resiliency may be higher or lower than reported.

Table 11. Percentages of the range that have each resiliency rating as analyzed under current condition, as well as if the "unknown" trajectories were all actually "stable" or all "decreasing."

		If "Unknowns" are:	
Resiliency	**Current**	**"Stable"**	**"Decreasing"**
High	11%	24%	11%
Moderate	72%	59%	25%
Low	17%	17%	64%

For each analysis unit, states were asked to provide a confidence ranking to accompany the demographic values provided, indicating if they had low, medium, or high confidence in their assessment of habitat availability, abundance, and trajectory of spotted turtles in each unit.

The analysis units that have high resiliency all have high or medium confidence in their assessments, while most of the analysis units with low resiliency have medium or low confidence (Table 12). Generally, the States had most confidence in their assessments for the analysis units in coastal areas (Figure 17).

Despite these uncertainties, our analysis of resiliency appears to generally align with the analysis of current habitat condition. Further, our state partners and other turtle experts were given the opportunity to review the resiliency categories and revisit and revise their data if they found discrepancies or inconsistencies. Therefore, we are confident in this methodology as representing the best available knowledge.

Table 12. Confidence rankings in the resiliency assessment for each analysis unit by L2 Ecoregion. Higher values fade towards darker blue.

Resiliency By L2 Ecoregion	Confidence in Assessment: High	Medium	Low	Dist. Of Resiliency
5.2	**Mixed Wood Shield**			
High	0.0%	0.0%	0.0%	0%
Moderate	0.0%	0.0%	3.1%	3%
Low	0.0%	0.0%	0.0%	0%
5.3	**Atlantic Highlands**			
High	0.3%	0.0%	0.0%	0%
Moderate	0.0%	2.6%	1.0%	4%
Low	0.0%	1.3%	0.1%	1%
8.1	**Mixed Wood Plains**			
High	2.1%	0.4%	0.0%	3%
Moderate	0.0%	11.6%	6.4%	18%
Low	0.0%	2.3%	1.1%	3%
8.2	**Central USA Plains**			
High	0.0%	0.0%	0.0%	0%
Moderate	0.4%	0.0%	6.7%	7%
Low	0.9%	4.0%	0.0%	5%
8.3	**SE USA Plains**			
High	0.0%	0.0%	0.0%	0%
Moderate	0.0%	10.2%	5.4%	16%
Low	1.9%	3.2%	0.0%	5%
8.4	**Appalachian Forests**			
High	0.0%	0.0%	0.2%	0%
Moderate	0.3%	5.9%	2.5%	9%
Low	0.4%	2.0%	0.0%	2%
8.5	**SE USA Coastal Plains**			
High	6.6%	1.3%	0.0%	8%
Moderate	0.7%	9.7%	5.2%	16%
Low	0.0%	0.1%	0.0%	0%
Dist. of confidence	14%	55%	32%	

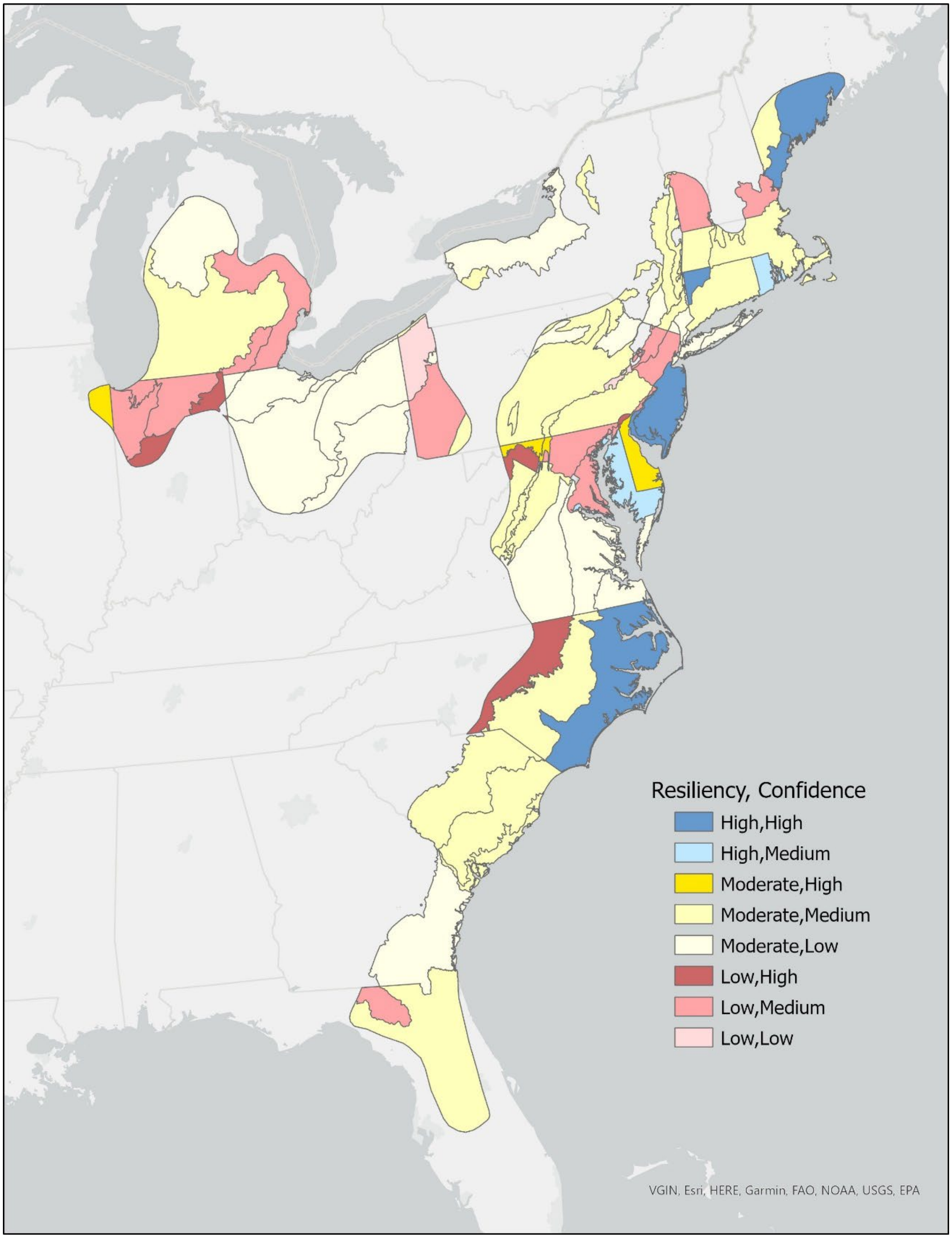

Figure 17. Confidence in the assessment of population density, habitat availability, and trajectory in each analysis unit by relative resiliency rating within the range of the spotted turtle.

5.5 Current Condition Summary

Spotted turtles use a wide variety of wetland types, both locally and across their range, occupying several distinct ecoregions, and the species can utilize different types of wetlands in response to varying local conditions throughout their activity cycle. Because this species exists in many different habitats that vary in connectivity, coupled with a lack of focused surveys or demographic data in much of the range, the current condition analysis is focused on identifying areas where the species appears to have relatively high resiliency and areas where it appears to have relatively low resiliency, with the rest of the range falling somewhere between. Based on our analysis, the species has relatively high resiliency in about 11 percent of its range, mostly along the east coast, relatively low resiliency in about 17 percent of the range, and the majority of the range is assumed to have relative moderate resiliency. However, the moderate resiliency category represents a wide spectrum of situations for the spotted turtle, encompassing both analysis units with relatively high abundance that are thought to be decreasing, as well as those with low abundance that are thought to be stable. Individual analysis units with a moderate ranking may fall on either end of this resiliency spectrum.

Looking at the abundance scores, the species is generally found in low abundances with restricted occurrence throughout most of its range. Habitat availability is higher along the coastal areas and habitat is naturally less common and more isolated further inland. The species has historically persisted in these areas with less habitat, so it is problematic to assume low abundance means low resiliency. While most of the range has unknown population trajectories, none of the analysis units were ranked as increasing (although some analysis units may have individual populations with increasing trajectories), and few analysis units are thought to be stable.

The species' long generation time means the spotted turtle may be undergoing declines that are not yet apparent via our measures of resiliency; for instance, populations may be comprised of only older individuals if there is not adequate recruitment. Little is known about spotted turtle demographics at sites across the range, but expert estimates of trajectory indicate that already at least 18 percent of the range is thought to be in population decline (USFWS 2023, unpublished data). The adaptive capacity of the species to respond to near-term or long-term changes in its environment is also uncertain, as it has some flexibility in the habitat it uses, but its long generation time likely means that it will be unable to keep up with the current pace of climate change (see Appendix A). While the species has adequate redundancy (given its wide range), the widespread loss of wetlands and observed population declines indicate that redundancy has decreased from historical levels.

6 FUTURE CONDITION

We have considered the influences on the needs and viability of the spotted turtle and the current condition of the species (Sections 4 and 5). We now consider the future condition of this species and apply future forecasts to the concepts of resiliency, redundancy, and representation to describe the future viability of the spotted turtle.

6.1 Methodology

The factors most likely to affect viability in the future are habitat loss and fragmentation; the loss of adults primarily due to collection and road mortality; and increasing temperatures and changing rainfall patterns, which will result in habitat loss but are also likely to have an impact of unknown magnitude on spotted turtle behaviors, activity patterns, and physiology. Each of these factors can be attributed directly or indirectly to one or both of two main sources: land use change and climate change (see Appendix B). Thus, to examine the probable future viability of the spotted turtle, we rely primarily on: (1) models of future land cover, specifically the change in amount of developed space and the change in areas classified as wetlands; (2) models of SLR and how that affects the distribution of marshes and wetlands; and (3) models of how temperature and precipitation are likely to change.

For this analysis, we assume that, regardless of current resiliency, both an increase in developed area within an analysis unit and a loss of wetland habitat, either through general land use changes or SLR, as well as the added impact of changes in temperatures and rainfall patterns, are likely to have a negative impact on resiliency of spotted turtle populations.

Scenarios

We assessed the future condition of the spotted turtle using models that predict future land use change and climate change. We chose to examine future condition at two timesteps, 2050 and 2100, roughly 25 and 75 years into the future. These time periods capture both a nearer-term assessment of future condition (approximately one generation) and a much longer-term assessment of the future given land use changes and climate change, while still staying within limits of available models. Climate models typically use 2100 as their endpoint, as beyond that timeframe, predictions become less certain. Thus, these timesteps also align with the available datasets for land cover and climate change (see below).

At each timestep (2050 and 2100), we forecast changes in resiliency under two climate scenarios (Mann 2022, entire; Sohl et al. 2014, p. 1015):

1) Moderate impact scenario: a lower trajectory for climate effects, using the SRES B1 land change scenario to forecast land cover change that would result from a lower emissions (Representative Concentration Pathway (RCP) 4.5) scenario and the Intermediate Sea Level Rise scenario.

2) High impact scenario: a higher trajectory for climate effects, using the SRES A2 land change scenario to forecast land cover that would result from a higher emissions (RCP 8.5) scenario and the High Sea Level Rise scenario.

Metrics

Habitat (Wetland) Loss

The amount of available habitat that currently exists within each analysis unit is already accounted for in our analysis of current condition, as is the impact of past land use. Thus, how much habitat is currently available and how much of the analysis unit is developed now is not factored into our methodology. However, how much these two metrics change in the future are assumed to impact resiliency. Thus, habitat loss is measured as the percent of the available wetland that is lost in each future scenario, regardless of how much exists now.

We projected wetland habitat loss due to: (1) general land use change, and (2) SLR.

Land Use Change

To project wetland loss via general land use change, we used the USGS Forecasting Scenarios of Land-use Change (FORE-SCE) model (Sohl et al. 2018, data release). The FORE-SCE dataset forecasts future land use that would result in different climate scenarios based on historical patterns and land use trends. The model incorporates socioeconomic data to model annual demand of each land cover type and includes forest stand age and the protection status of lands (from the PAD-US dataset (USGS 2022, dataset)) when determining a future land use in an area (Sohl et al. 2014, p. 1018). We used the B1 and A2 scenarios to bound our range of future changes. This model, therefore, predicts what land use trends would lead to more moderate climate impacts (using the SRES B1 scenario) and higher climate impacts (using the SRES A2 scenario) (Sohl et al. 2014, p. 1018). To measure land use change, we calculated the area (hectares/acres) that is projected as wetland (both Herbaceous Wetland and Woody Wetland categories) at the 2019 timestep, as well as at each of our future timesteps under both scenarios. For each scenario, we calculated the change in wetland cover as the percent of the existing wetland (2019) that is gained or lost at each timestep. Because the 2019 timestep is already a projection (the dataset projections begin in 2006; Sohl et al. 2014, p. 1016), this change in percent wetland is meant to help interpret the general trend in each analysis unit, as a means to compare among units. We used percent of the existing wetland habitat that is lost to describe the direct impact to spotted turtles.

Sea Level Rise (SLR)

To project wetland lost due to SLR, we used the SLR viewer (NOAA 2023, online tool) to determine the projected SLR at each of our timesteps for every local scenario within the range of the spotted turtle. We averaged these local scenarios by state to get a state average SLR for each scenario and timestep. These were rounded to the nearest half-foot to correspond to the NOAA Marsh Migration data layers, which provide the existing marshes (at 0 ft SLR) and projected areas where marsh will be lost and gained for each 15.24 cm (6 in) of SLR. We classified the marsh types as primary habitat (Palustrine Forested Wetland, Palustrine Scrub/Shrub Wetland, and Palustrine Emergent Wetland) or secondary habitat (Brackish/Transition Wetland, and

Estuarine Wetland). All other classifications are not considered wetland habitat (unconsolidated shore, open water, uplands, developed). Projected SLR results are provided in Table 13.

For each scenario and timestep, we calculated both the total habitat and primary habitat only that is gained or lost as the percentage of existing habitat lost or gained, and we used the higher value as the percent habitat lost.

Table 13. Feet of sea level rise at each timestep under both scenarios averaged by state and rounded to the nearest half a foot. Values are averages of each of the local scenarios provided in the NOAA (2023a, entire) Sea Level Rise viewer that exist in or near each state.

	Sea Level Rise (ft)			
	2050		2100	
State	**Mod.**	**High**	**Mod.**	**High**
Maine	1.0	1.5	3.5	6.0
New Hampshire	1.0	1.5	3.5	6.0
Massachusetts	1.5	1.5	4.0	6.5
Rhode Island	1.5	1.5	4.0	6.5
Connecticut	1.5	1.5	4.0	6.5
New York	1.5	1.5	4.0	6.5
New Jersey	1.5	2.0	4.0	7.0
Pennsylvania	1.5	1.5	4.0	6.5
Delaware	1.5	1.5	4.0	6.5
Maryland	1.5	1.5	4.0	7.0
Virginia	1.5	2.0	4.0	7.0
North Carolina	1.5	1.5	4.0	7.0
South Carolina	1.0	1.5	4.0	7.0
Georgia	1.0	1.5	4.0	7.0
Florida	1.0	1.5	3.5	7.0

Habitat Loss Impact

To calculate an impact value due to habitat loss for each analysis unit, we added the two metrics: percent lost to land use change and the percent lost from SLR. While in some cases the habitat that is lost may overlap and be counted in both metrics, the metrics are measuring two different things. The SLR analysis only uses habitat existing along the coastal areas, and wetlands are mapped differently in each dataset, so we opted to keep these measures separate. Thus, their sum does not indicate the percent of the total habitat that is lost, but the value is meant to provide a general way to classify the extent of habitat loss. If this sum is less than 5 percent (or there is a gain in habitat), then we assume there is no impact. If more than 40 percent of the existing habitat is lost, then we consider the impact to be high. Impact values are provided in Table 14.

Table 14. Relative impact values for various amounts of existing habitat that is lost within an analysis unit, binned by none, low, moderate, and high.

Sum Percent Habitat Lost	Impact	Impact Value
≤5	None	0
>5 to 20	Low	1
>20 to 40	Moderate	2
>40	High	3

Development

While we already accounted for the direct loss of wetland habitat due to land use change, additional development (urban and suburban sprawl, etc.) in an analysis unit (that does not directly impact wetlands) was not captured and will likely have further indirect effects on the spotted turtle. Additional development is correlated with additional roads, which increases the risk of road mortality, more human access/activity and therefore more opportunities for disturbance or collection, and a higher risk of altered hydrologic conditions and pollution. While the habitat lost due to land use change calculates the amount of wetland projected at each timestep and how the amount changes from current (2019), this additional metric calculates how much the amount of development in an analysis unit, specifically how much more area becomes developed.

To get at this additional threat, we used the FORE-SCE model to project the total additional percent of the analysis unit that will be developed in the future. For each scenario, we calculated the difference between the percent of each analysis unit projected to be developed in 2019 and the percent at each of our future timesteps. Because the 2019 timestep is already a projection (the dataset projections begin in 2006; Sohl et al. 2014, p. 1016), this change in percent development is meant to depict the general trend in each analysis unit and compare among units. This analysis does not account for what the actual current development percentage is, and existing impacts from development are assumed to be captured in the current condition.

If less than five percent of the analysis unit is projected for additional development, we assume there will be no impact. If more than an additional 40 percent of the analysis unit is projected as developed, we consider this a high impact. Impact values are provided in Table 15.

Table 15. Relative impact values for each level of additional development within an analysis unit, binned by none, low, moderate, and high.

Additional Percent Analysis Unit Developed		Impact Value
≤5	None	0
>5 to 20	Low	1

Additional Percent Analysis Unit Developed		Impact Value
>20 to 40	Moderate	2
>40	High	3

Summation

We added these impact values (habitat loss and development) to get a total impact value for each scenario at each timestep. The impact of habitat loss was weighted higher than development, counting this impact twice, to account for the direct loss of habitat that would have a larger impact than general development in the analysis unit. For each combination of this summed habitat impact value and the current resiliency in the analysis unit, we assigned a risk of extirpation to each analysis unit (Table 16). This risk should be interpreted as the risk that individual populations within the analysis unit will become extirpated.

Table 16. Classification of future condition given an analysis unit's current resiliency rating and the future impact magnitude (combination of habitat loss and development).

<table>
<tr><th rowspan="2">Habitat Impacts</th><th colspan="3">Current Relative Resiliency Rating</th></tr>
<tr><th>High</th><th>Moderate</th><th>Low</th></tr>
<tr><td>0</td><td rowspan="4">Likely viable</td><td rowspan="2">Likely viable</td><td rowspan="2">Moderate risk of extirpation</td></tr>
<tr><td>1</td></tr>
<tr><td>2</td><td rowspan="2">Moderate risk of extirpation</td><td rowspan="8">High risk of extirpation</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td><td rowspan="2">Moderate risk of extirpation</td><td rowspan="6">High risk of extirpation</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td><td rowspan="4">High risk of extirpation</td></tr>
<tr><td>7</td></tr>
<tr><td>8</td></tr>
<tr><td>9</td></tr>
</table>

For reference, losing a sum of more than 20 percent of the available habitat in an analysis unit would be an impact of 4, given no other impacts, while losing more than 40 percent is an impact of 6.

Climate

While the FORE-SCE model incorporates land use changes that result in different climate scenarios and we also consider SLR in our projections of habitat loss and development, climate change can negatively impact spotted turtles in additional ways. The most likely impacts to spotted turtles from climate change include habitat loss from drying of wetlands, which is caused by changes in precipitation patterns and timing, and changes in activity patterns due to excessive heat or extended periods of heat that would lead to a decrease in activity and thus impact their ability to perform normal functions (forage, reproduce, etc.). Increases in temperatures could also affect sex ratios of spotted turtle nests. Spotted turtles at the southern edge of the range are assumed to already be at the higher end of their thermal range (Willey et al. 2022, p. 147). An increase in average ambient temperatures and very hot days in a season would both increase the likelihood of wetland drying as well as decrease the activity of individual turtles. Thus, we further accounted for the biological (habitat and physiological) impact of climate change on the spotted turtle by considering the magnitude and nature of how the climate is likely to change within the range of the species.

While we know that the climate is changing and that temperatures are generally trending upwards, models of precipitation are less certain (see Section 4.2). Because the specific impacts of climate change on spotted turtles are uncertain and will vary by local temperature and precipitation conditions, and how these changes are likely to interact and impact habitat and individuals, we are unable to make specific predictions of climate impacts. However, we are able to make some assumptions about the general impacts of climate change and some regional predictions.

Thus, we assume that the likelihood or intensity of potential effects to the spotted turtle due to climate change will increase:

1. Over time, such that climate effects at the 2100 timestep will be more likely to impact spotted turtles than the 2050 timestep, and

2. With the higher impact climate scenario, such that climate effects under the higher emissions scenario will be more likely to impact the spotted turtle than the lower emissions scenario.

Further, we make some generalizations about the impacts of climate change by region (northeast, from Maine to Maryland; midwest, western New York and Pennsylvania west to Michigan; and southeast, from Virginia to Florida), given the specific predictions and existing models of future temperature and rainfall and how they differ across regions. We then determine how these potential impacts are likely to affect the resiliency of analysis units and account for this risk separately.

6.2 Results

Habitat Loss and Development

Habitat loss is projected to be higher along the coastal analysis units, mostly due to the added impact of SLR and marsh migration (Figure 18). By 2050 under a high scenario, only areas in South Carolina and Florida lose over 40 percent of the available habitat, per our calculations, but by 2100, areas all along the coastal range lose this level of habitat. A high climate scenario also indicates increased levels of development in some of the range in the midwest (Figure 18).

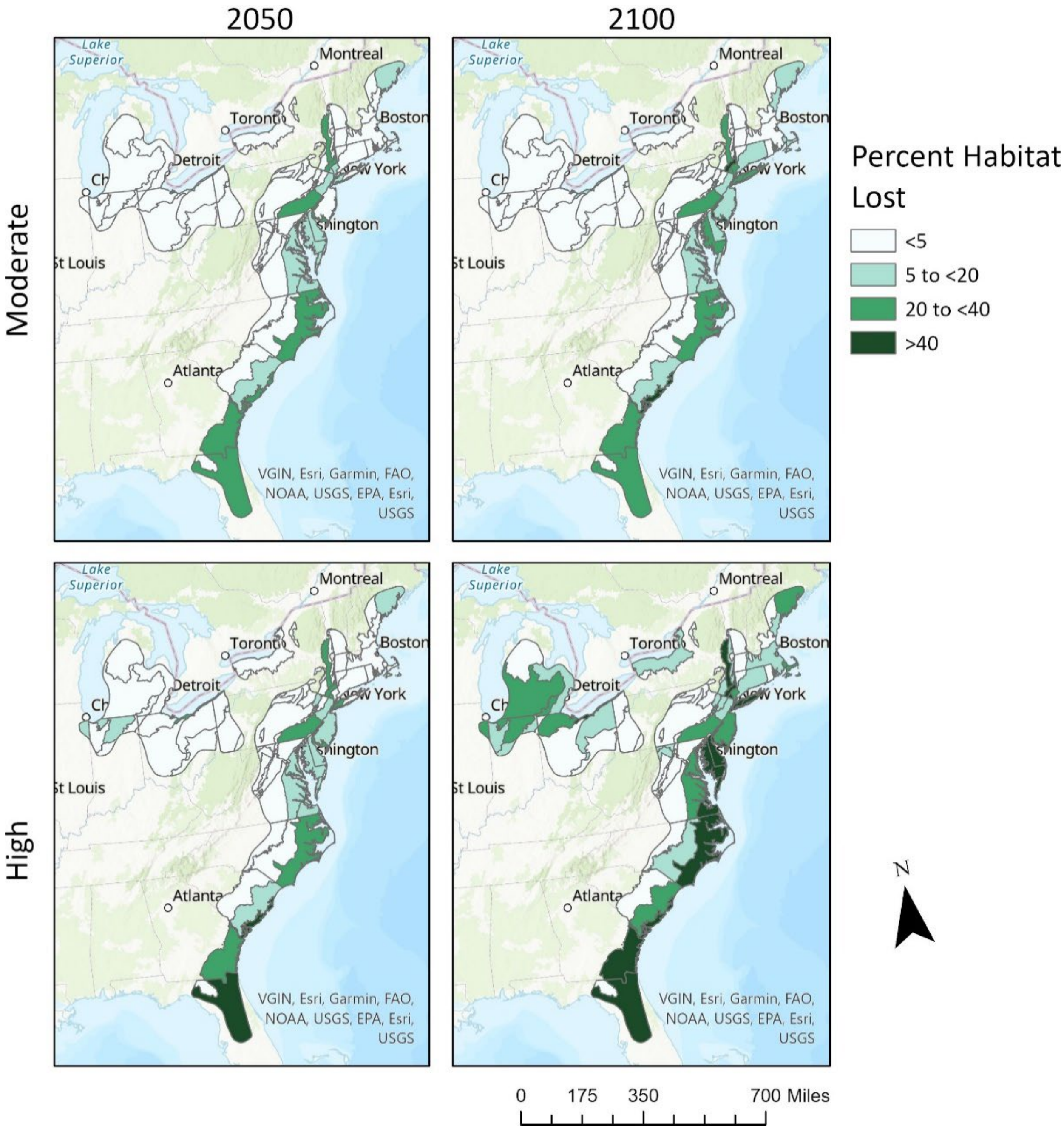

Figure 18. Percentage of available habitat that is projected to be lost for each analysis unit under each scenario (moderate and high) at each timestep (2050 and 2100), per our calculations outlined in Section 6.1.

Additional future development (>5 percent of analysis unit) is not projected to be widespread by 2050, and there is not much difference between the two climate scenarios (Figure 19). However, by 2100 under a moderate climate scenario, future development is fairly concentrated in the coastal areas between Virginia and Massachusetts, but under a high scenario, development is much more widespread in all regions. No analysis units see more than 40 percent additional area developed under any scenario (Figure 19).

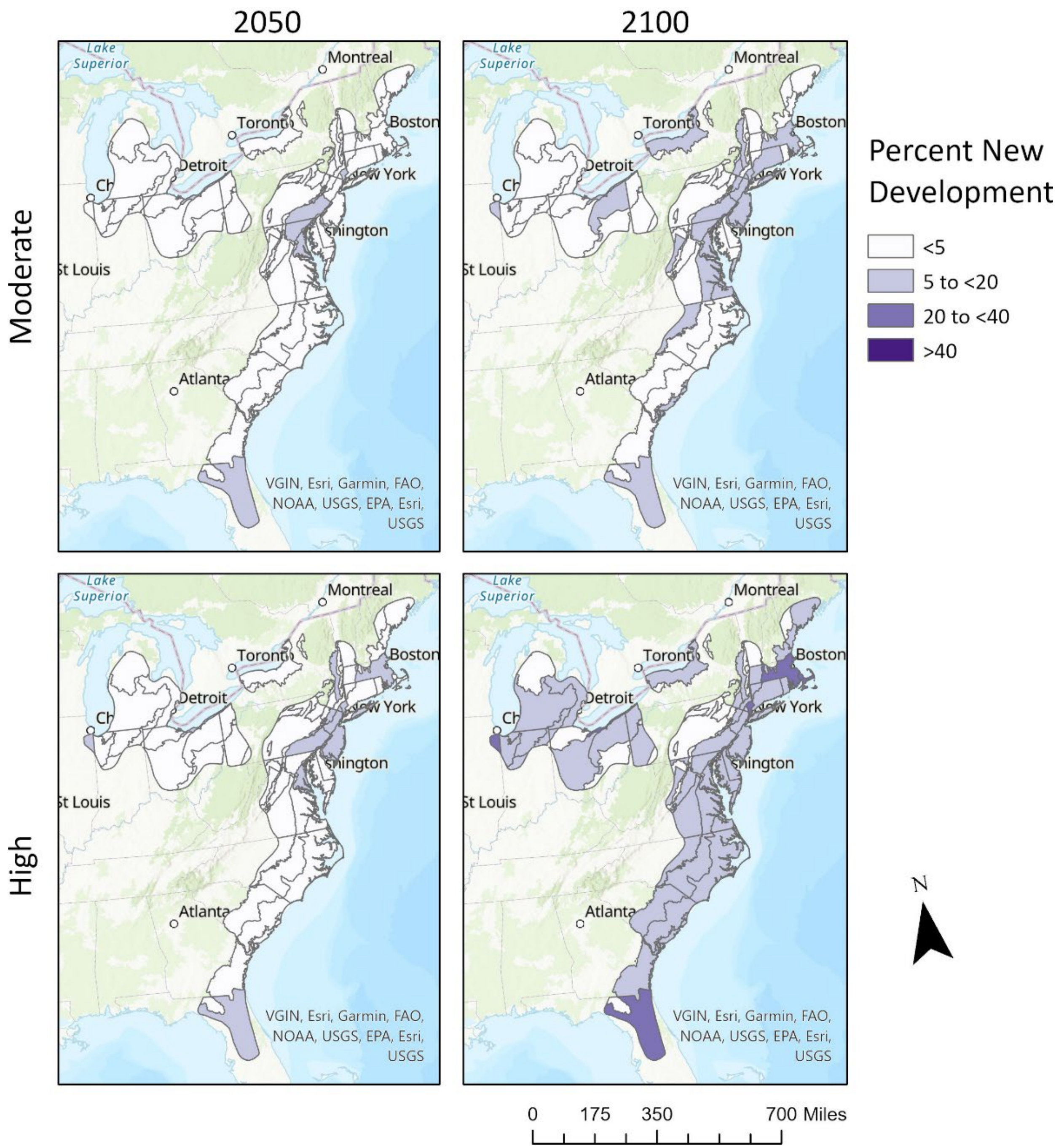

Figure 19. Percentage of each analysis unit that is projected to be developed (new areas of development) under each scenario (moderate and high) at each timestep (2050 and 2100).

Combining habitat loss impacts and development impacts, we find that impact levels are highest in Florida and one ecoregion in Pennsylvania under both scenarios by 2050; however, generally impacts in coastal areas are higher than those regions more inland (Figure 20). By 2100, impacts become more widespread and much higher under a high climate scenario (Figure 20).

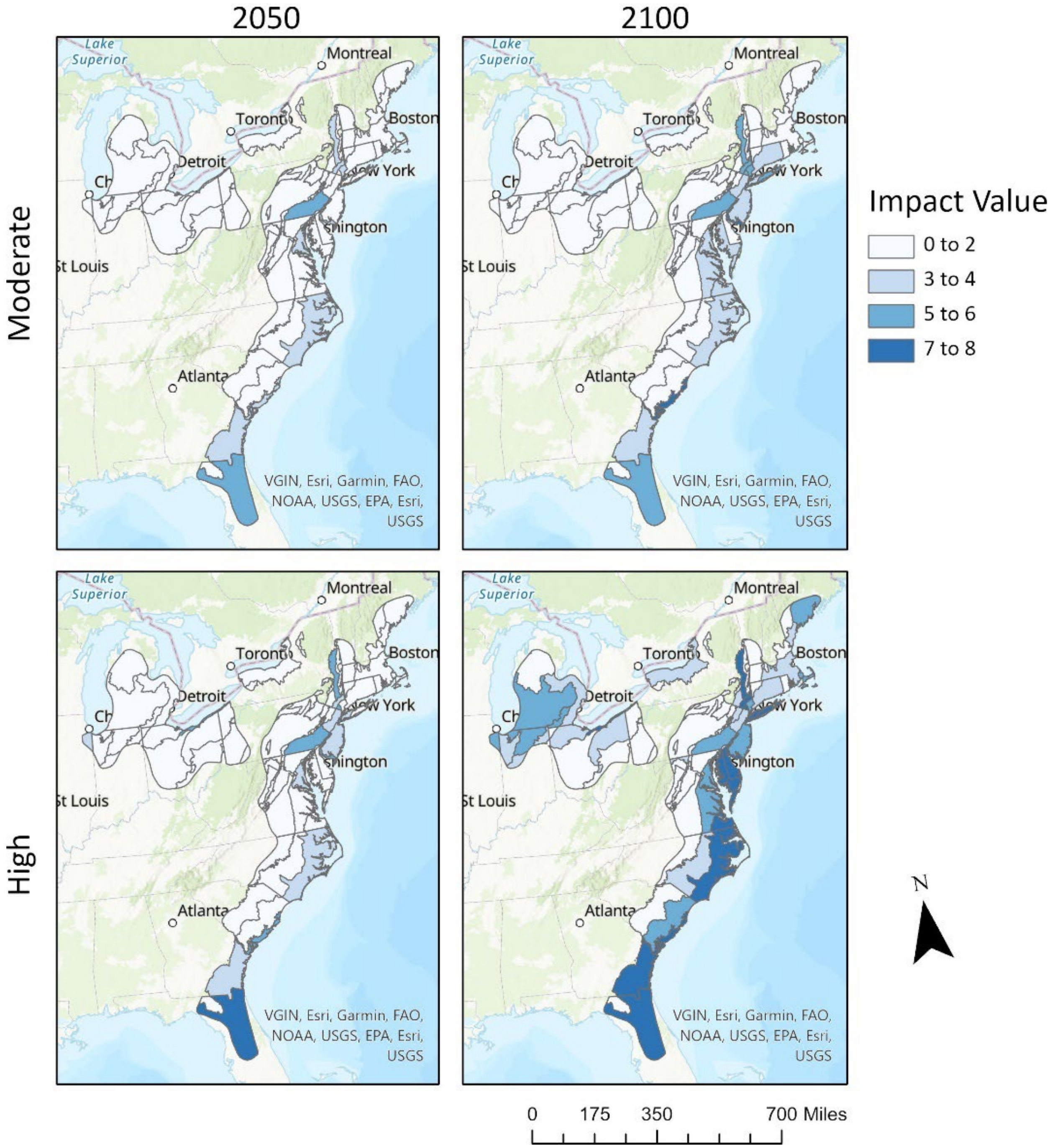

Figure 20. Impact value (a combination of habitat loss impact and development impact) per our calculations outlined in Section 6.1 for each analysis unit under each scenario (moderate and high) at each timestep (2050 and 2100).

Climate

Generally, we know that temperatures will warm across the range, but the magnitude of increase in average temperature is expected to be greater in the northeast and midwest regions than the southeast (see Figure 7). However, the number of very hot days (ambient temperature over 38 °C (100 °F); critical thermal max of spotted turtles = 41.7 °C (107 °F)) will see a larger increase in the southeast region than the rest of the range (see Figure 8). While precipitation models vary greatly, evidence suggests that annual rainfall will increase in the northeast and midwest and potentially in the southeast, although the timing and intensity of precipitation is unknown and may result in more floods. However, we expect that droughts will become more common, especially in the southeast, and the added impact of more very hot days (>100 °F) will exacerbate the potential of these droughts to dry out wetland habitats for periods that are incompatible with spotted turtle occupancy. These impacts culminate in a generally lower potential impact of climate change in the northeast and midwest regions, and a higher potential impact of climate change in the southeast (Table 17).

Table 17. General climate change summary and potential impacts to the spotted turtle by general region within the range.

Region	Climate summary	Species impacts
Northeast	Generally more annual rainfall, potential increasing flood events. Average temperatures increasing.	Increase in annual precipitation will mean sufficient snowpack and rainfall to maintain wetlands and vernal pools (groundwater). Increasing heat may impact behaviors, but position in northern portion of range likely means they can adapt.
Midwest	Generally more annual rainfall, mostly in the spring, potentially increasing flood events; droughts are uncertain. Average temperatures increasing more than in other parts of the range.	Increased spring rainfall will likely maintain wetlands. Increasing heat may impact behaviors, but position in northern portion of range likely means they can adapt.
Southeast	Potentially more annual rainfall, but more unpredictable and sporadic rainfall events, increasing the risk of droughts and flood events. Average temperatures increasing some, but triple-digit (>100°F) days increase a lot.	Increase in heat and less consistent rainfall will increase chances of wetland drying. Increased heat days will impact turtle behaviors and timing, and the position in the southern portion of the range means there is a high risk of these impacts impacting viability.

Due to the relationship between increased temperatures and the threat of wetland drying, given that rainfall patterns cannot be easily predicted, and because high ambient temperatures near the critical thermal max can lead spotted turtles to spend time estivating to keep cool, we are primarily using the future projections of triple-digit days to assess the threat of climate change in the southeast. While impacts from climate change are expected to some extent across the range at both timesteps and in both scenarios, the best available information indicates that climate change impacts in the midwest and northeast are not great enough to have a major impact on viability across those regions; increasing average temperatures and increased heat days will still remain below what the species currently experiences in the southeastern portion of the range (Table 17). In the southeast, where the threat of climate change is greater, the actual impacts of added days over 38 °C (100 °F) are uncertain, as the species currently exists where average days over 38 °C (100 °F) approach 10 days in some areas within the region. However, once the average number of these very hot days triples, we expect that the impacts to spotted turtles will be increased enough to significantly increase the risk of extirpation.

Models of temperature increases (averaged over 32 climate models; LOCA 2023, dataset) indicate that the number of days over 38 °C (100 °F) stay below 30 throughout the range until 2100, increasing to above 30 days on average only under a high climate scenario and only in the southeast region, with states from Virginia to Florida seeing on average between 30 and 80 days of these temperatures annually (see Figure 8). While we do not know the full impact of these heat days, the southeast region will have additional significant impacts from climate change by 2100 under a high scenario, which will elevate the risk of local or potentially widespread population extirpations (see Figure 21).

6.3 Future Resiliency

By 2050, analysis units where populations are likely to remain viable are mostly in the interior of the range, inland from the coast and the midwest region, as well as within the northernmost regions of New England. The highest risks of population extirpations are generally within the southernmost areas in the range and along the eastern portions of Pennsylvania (Figure 21). This remains true by 2100 under a moderate scenario, but under a high scenario by 2100, most of the coastal regions and much of the midwest analysis units have a high risk of population extirpations, with the southeast having the added risk of climate impacts (Figure 21).

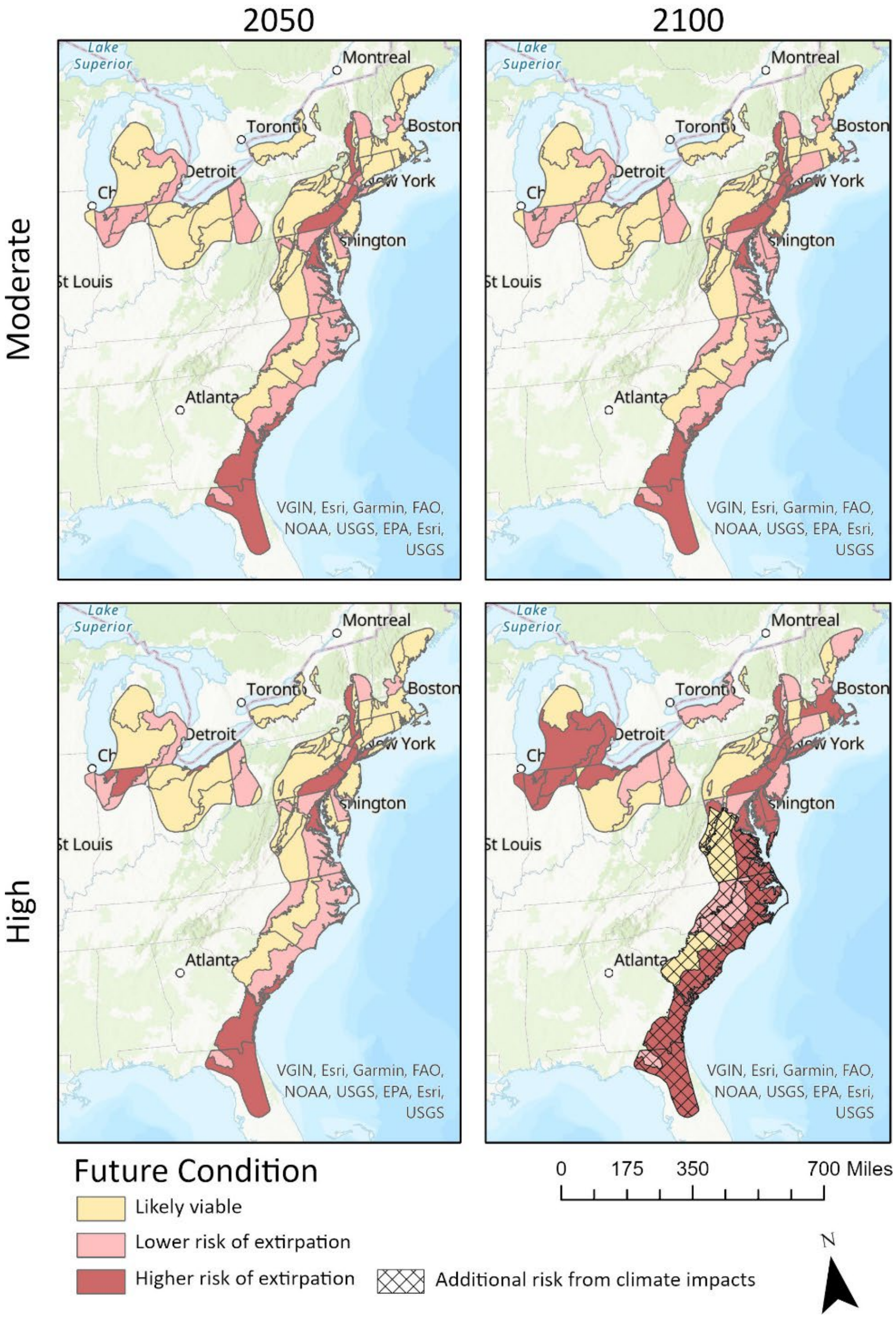

Figure 21. Projected future condition of the spotted turtle. Risk of extirpation refers to localized or widespread population extirpations within each analysis unit. While we cannot accurately quantify the additional risk of climate change, the best available

information suggests that climate change will increase the risk of extirpation in the southeast region.

By area, more than half of the range is likely to remain viable in 2050, regardless of the climate scenario, and more than half of the range remains viable by 2100 under a moderate climate scenario (Table 18). However, under a high climate scenario by 2100, almost half of the range will see higher risks of population extirpations (Table 18). The areas that are likely to see the highest risk of extirpation are also the areas where habitat is currently most available and where the species is more abundant; thus, the percent of the range does not account for population abundance or the strongholds for the species.

Table 18. The percentage of the spotted turtle range that is expected to likely remain viable or have a moderate or high risk of extirpation in the future under both scenarios at both timesteps.

	Percent of Range			
Future Condition	**Mod 2050**	**High 2050**	**Mod 2100**	**High 2100**
Likely viable	57.2	56.7	53.4	29.6
Moderate risk of extirpation	28.5	26.7	31.3	23.8
High risk of extirpation	14.3	16.6	15.4	46.6

6.4 Future Redundancy and Representation

While we do not foresee entire analysis units being extirpated under either of our scenarios or at either timestep, some population losses are possible, especially in highly developed analysis units and regions near the southern extent of the range. Impacts are likely to lead to the expiration of localized populations within analysis units, especially in analysis units where the future condition indicates a higher risk. Thus, we expect that redundancy will be lower under all future scenarios, with the largest decrease under the high scenario by 2100.

While there are no discrete genetic “types” of spotted turtles, representation may be decreased in the future due to a loss of populations in specific habitat types, such as those available in the Southeast USA Coastal Plain. This entire area is at high risk of extirpation under a high climate scenario by 2100. Climate change impacts and the added impacts of habitat loss (including due to SLR) and development could cause populations in coastal habitats to disappear, especially in the furthest southern portions of this region.

6.5 Uncertainties

The same uncertainties and knowledge gaps regarding the current condition mean that there is uncertainty in the starting point onto which we apply our future condition. This, coupled with additional uncertainties regarding our analysis methods for future condition, could lead to inaccurate estimates of the future condition of spotted turtle across the species’ range.

The methods and models used in our analyses of future condition provide additional uncertainties, which include:

- Because future condition is determined in part by the current condition category (high, moderate, or low resiliency rating), future condition and the risk of extirpations may be inaccurate in some analysis units. This is especially true for analysis units with a moderate current resiliency rating where the trajectory is unknown (39 analysis units of 50); if trajectories there are decreasing, then the future projection would be a higher extirpation risk. While this could be over- or under-estimating the future viability of spotted turtles, based on our analysis methods that were meant to be conservative, this is more likely to be overestimating future viability.
- The future projections we used are models and may not represent future realities. Future developments may not be limited to the areas forecast in the models, marsh migration and SLR may impact areas differently than modeled, habitat that is not mapped may be lost or gained, and climate change may impact regions differently than models indicate. These uncertainties may either over- or under-estimate the future viability of spotted turtles.
- Additional threats to populations may exist that are location-specific or random or otherwise not captured by our modeling. For example, invasive plant species resulting in habitat degradation and loss would not be captured from our modeling, although this may be loosely correlated to development. Likewise, threats that are thought to be correlated with our modeling may exist in other locations; for instance, collection may be high in areas away from development. Thus, our analysis may over-estimate resiliency.
- The true impact of climate change, specifically heat days and changing rainfall patterns, is unknown. It is possible that climate change is already impacting spotted turtle resiliency and will have impacts sooner and in other regions than projected, and it is possible that climate change will not have major effects on some populations until outside our timeframe for the foreseeable future (2100). Impacts may render entire analysis units uninhabitable. At some point, temperatures will exceed spotted turtle tolerances, but when this threshold will be reached and how a changing climate will specifically impact spotted turtle populations is unknown. Our analysis may either over- or under-estimate the effects of future climate change on spotted turtles.
- The realized impact of additional development is unknown. While we assume that an increased amount of development within the analysis unit will have negative impacts on the spotted turtle populations, we are uncertain where these impacts will occur within an analysis unit and whether occupied spotted turtle areas will be affected. This could either over- or under-estimate the future viability of spotted turtles.

- We also do not know how the recent Sackett vs. EPA ruling will impact federal protection of non-tidal and ephemeral wetlands rangewide. This could result in an over-estimate of the future viability of spotted turtles.
- The future condition may not accurately represent the entire analysis unit. Given the scale of our analysis units (Level III Ecoregions and state boundaries), there may be some areas where there are low impacts, despite the entire analysis unit ranking as having a high risk of extirpations, and vice versa. This may be especially true in analysis units that have a moderate current resiliency rating, as these were more likely to have a mixture of both resilient and non-resilient populations of spotted turtles. This could either over- or under-estimate the future viability of spotted turtles.
- The projection of future impacts and their magnitude may be inaccurate. Additional threats that are not captured in our models of land use, habitat loss, or climate change may occur and drive otherwise resilient populations to extirpation. For instance, collection or high levels of predation could cause an otherwise resilient population to crash, and while we assume these threats are correlated to increased development, there are likely to be places where this correlation does not hold. This could lead to an over-estimation of future condition.
- Conservation efforts may offset some of the magnitude of impact. Some populations may be stabilized or improved as a result of targeted conservation efforts; however, what and how much conservation are implemented, and where these beneficial conservation actions occur, is uncertain and will vary across the range. This could be under-estimating the future condition of spotted turtles.
- While our methods model habitat loss, this species' ability to occupy so many diverse wetland types means that not all wetlands that spotted turtles use are mapped; vernal pools, ditches, and other small wetlands are unlikely to be accounted for in this future condition analysis. Thus, habitat loss may be more or less pronounced, depending on the region, and this could over- or under-estimate future condition, depending on whether unmapped habitats become lost in the future.

6.6 Conclusions

Spotted turtles within the majority (72 percent) of the range currently cannot be classified for certain as having high or low resiliency, but instead they likely fall somewhere between, with much of this area having unknown trajectory, moderate abundances, and somewhat restricted occurrences (Figure 14). The eight relatively abundant, seemingly stable analysis units (with a high resiliency rating) comprise about one tenth of the range and exist mostly along the Atlantic coast, distributed from North Carolina northwards to Maine. The locations where it has generally low resiliency characterized by low abundance, fragmented habitats, and declining population trajectories, make up about 17 percent of the range and are spread out across the range (Figure 14). While we can predict that the highly resilient populations will likely fare well given increased future threats, and that the low resiliency populations are likely to have a higher risk of extirpation, most of the range exists in the middle. Additional surveys conducted in these moderately resilient analysis units to determine which populations are stable and which are declining would likely have a large impact on predictions for their future risk of extirpation. For instance, the most recent surveys in the Northern Indiana Drift Plains ecoregion in Michigan indicate that spotted turtles may not be as abundant as previous data indicated, and additional surveys may indicate that the species is not as resilient in this ecoregion as reported (Lee 2023, pers. comm.).

The populations that have the highest risks of extirpation based on this analysis exist within the areas that have moderate to high abundance scores, while the majority of the regions expected to remain viable are where the species currently exists in relatively low abundance (see Figure 13, Figure 21). Coastal regions, which contain the current population strongholds for the species, also have higher risks of extirpation.

Habitat loss will be the most severe in the coastal areas due to SLR and the resulting marsh loss or migration inland. However, habitat loss due to land use changes becomes more likely within the more interior areas given a higher climate scenario by 2100, when the threat of development is also expected to increase. While the realized impacts of development are less certain, the loss of habitat has a direct impact on spotted turtle populations. Climate change is almost certain to have some future impact on spotted turtle populations, but the timing and magnitude of that impact is less certain. Changing rainfall patterns and increasing temperatures can have impacts ranging from causing habitat loss, causing individual mortality, helping the spread of invasives, altering the active period of turtles, shifting sex ratios, and reducing individual fitness.

While it is difficult to make assumptions about the level of impacts that would cause populations or entire analysis units to become extirpated, this analysis does not mean that a high risk of extirpation equals extirpation, although it also does not indicate that complete extirpation of the analysis unit is impossible. While the greatest anticipated threat to a reduction in range of the spotted turtle exists in the southernmost analysis units, where increasing temperatures may limit reproduction and alter behaviors, other unforeseen threats that could cause widespread extirpations are possible. For example, the 2023 U.S. Supreme Court ruling *Sackett* v. *the Environmental Protection Agency* essentially removes protections to "...any wetland that does not connect at its surface to another body of federally protected water," weakening the reach of the Clean Water Act and limiting the existing and available future protections to spotted turtle habitats.

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APPENDIX A: ADAPTIVE CAPACITY

We assessed the potential adaptive capacity for the spotted turtle using the methodology outlined in Thurman et al. (2020, entire). Adaptive capacity, the ability of a species to cope with or adjust to climatic or other habitat changes, is evaluated using an attribute-based framework that identifies two general classes of adaptive responses: "persist in place" and "shift in space." Persist in place attributes assess the species' ability to survive within their current distribution and shift in space attributes assess the ability of the species to shift their distributions as existing areas become unsuitable. Each of 36 individual attributes is evaluated using relative values (high, moderate, and low); 12 core attributes represent those that are particularly important. This assessment is not meant to provide a single overall metric of adaptive capacity, but instead provides an understanding of the strengths and limitations of potential adaptive capacity for a species (Thurman et al. 2020, entire).

Using the metrics provided by Thurman et al. (2020, web table 2), the spotted turtle ranks high on 14 (45 percent) of the total known, applicable factors (4 factors on migration are not applicable; age structure is unknown), moderate on 10 (29 percent), and low on 8 (26 percent) (Table A1; Figure A1). Of the 12 core factors, the spotted turtle ranks high on four (33 percent), moderate on six (50 percent), and low on two (17 percent) (Table A1; Figure A1).

The species appears to have some ability to both adapt in place and shift their distribution, ranking high or moderate on over half of the attributes overall, just in the core 12, and looking at the attributes by shift in space or persist in place. However, habitat availability and fragmentation may impede the spotted turtle's ability to move in response to climate change. Likewise, spotted turtle demography, specifically their long lifespan and generation time may impede their ability to adapt quickly enough to changing conditions to outpace climate impacts.

Table A1. Rankings of the 36 attributes used to assess adaptive capacity of the spotted turtle, with the 12 core attributes highlighted in blue.

		Attribute	Value	Notes	Citation
Shift in Space	Distribution	Extent of Occurrence	high	>20,000 km2	Ernst and Lovich 2009, p. 213
		Area Of Occupancny	high	>2000 km2	Willey et al. 2022, pp. 3–4
		Habitat Specialization	moderate	While found in varied wetland habitat types, wetlands still rare in the landscape.	USFWS 2023, unpublished
		Commensalism w/Humans	moderate	Can use semi-natural landscapes, such as irrigation ditches, etc.	Willey et al. 2022, p. 14
		Geographic Range	moderate	Broadly distributed with sparse or isolated populations	USFWS 2023, unpublished
	Movement	Dispersal Syndrome	high	Facultative	Liebgold et al. in review, p. 14
		Dispersal Distance	high	Move more than 1 km	Liebgold et al. in review, p. 14
		Dispersal Phase	high	Can disperse throughout life	Liebgold et al. in review, p. 14
		Site Fidelity	low	High site fidelity	Willey et al. 2022, pp. 39–40
		Migration Frequency	NA		
		Migration Demography	NA		
		Migration Timing	NA		
		Migration Distance	NA		
Shift in Space and Persist in Place	Evolutionary Potential	Genetic Diversity	high	High heterozygozity comparatively	Davy and Murphy 2014, pp. 150–154
		Population Size	low	Populations typically <250 adults	
		Hybridization Potential	low	No hybridization known	
	Ecological Role	Competitive Ability	high	No known competitors that might outcompete it.	
		Diet Breadth	high	Flexible diet, omnivorous	Ernst 1976, pp. 27-28; Ernst and Lovich 2009, p. 220
		Diversity of Obligate Spp	high	Diffuse interactions	
	Abiotic Niche	Seasonal Phenology	moderate	Timing of hibernation and emergence can shift some, but amount unknown.	Ernst 1976, p. 26; Ernst and Lovich 2009, p. 214; Haxton and Berrill 2001, p. 606
		Climate Niche Breadth	moderate	Moderately dependent on rainfall amounts/timing	Ernst and Lovich 2009, p. 214; Joyal et al. 2001, p. 1755; Milam and Melvin 2001, p. 418
		Physiological Tolerances	moderate	Lethal effects of climatic changes unlikely, but sublethal effects likely.	See Table ...
		Behaviroal Reg. of Physiology	moderate	Thermoregulation (senesence) possible, but interferes with time foraging.	Willey et al. 2022, p. 147
Persist in Place	Life History	Reproductive Phenology	moderate	Nest throughout a range of dates.	Ernst 1970, p. 228; Litgus and Brooks 1998a, p. 252; Litzgus and Mousseau 2006, p. 132
		Reproductive Mode	moderate	Oviparous	Ernst 1970, p. 229
		Mating System	high	Promiscuous mating	Ernst 1970, p. 228
		Fecundity	moderate	mean clutch size 3 to 5	van Djik 2011, p. 2
		Parity	high	Reproductive multiple times.	Litgus and Brooks 1998a, p. 252
		Sex Ratio	high	Balanced	Ernst 1976, p. 28
		Sex Determination	low	Temperature-dependent	Ernst and Lovich 2009, p. 219
		Parental Investment	high	Precocial	Ernst and Lovich 2009, p. 219
	Demography	Lifespan	low	>25 years	Litzgus 2006, p. 281; van Djik 2011, p. 2
		Generation Time	low	likely 20 to 30 years	van Djik 2011, p. 2
		Age of Sexual Maturity	high	Early relative to lifespan (7-12 years, 30+ lifespan)	Feng et al. 2019b, p. 7; Litzgus 2006, p. 281; van Djik 2011, p. 2
		Age Structure	low	Typically adult-biased.	Feng et al. 2019a, p. 648
		Recruitment	low	Low juvenile survival	Feng et al. 2019a, p. 650

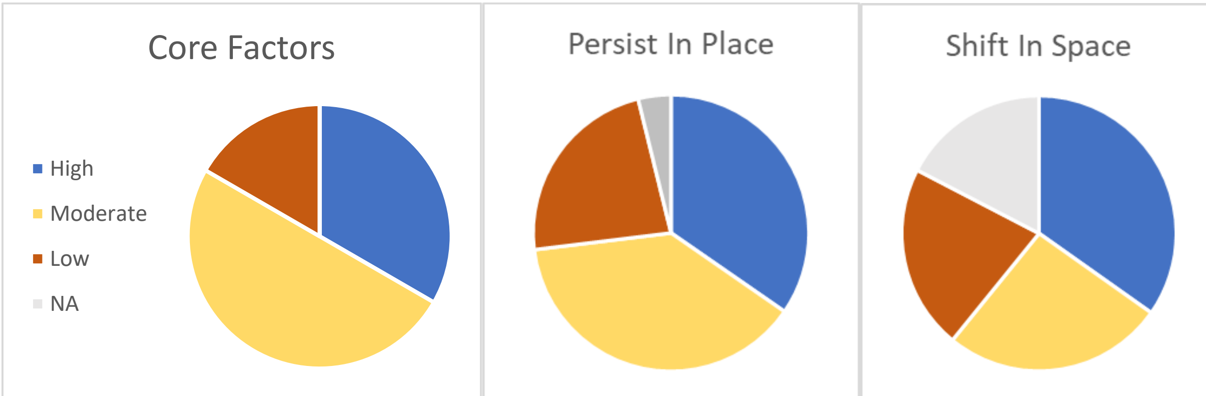

Figure A1. Percent of spotted turtle adaptive capacity attributes ranking as high, moderate, low, or not applicable (NA) for only the 12 core factors (left), for those factors that assess the ability of the species to survive within their current distribution (persist in place; center), and for only those factors that assess the ability of the species to shift their distributions as existing areas become unsuitable (shift in space; right).

APPENDIX B: FUTURE IMPACTS

Table B1. Major future impacts to spotted turtles due to land use changes and climate change, including the timeframe and confidence of both the change and the species' response.

	Threat	Timeframe	Confidence	Species Response	Timeframe	Confidence	Reference(s)
Land Use	Habitat loss and fragmentation from land use change including development, infrastructure, agriculture, etc.	Current and continuing	High Confidence that land uses will continue to change such that habitat is affected; Moderate Confidence of specific locations of this change (but can be modeled generally).	Loss of suitable habitat (all stages) and habitat degradation, changes in water quality and quantity which can lead to reduced fitness, direct loss of individuals (increased road mortality, increased predation, more collection, etc.).	Currently occurring and expected to continue to occur within the near future	High Confidence that habitat impacts will affect spotted turtle demographics and that direct mortality will result in some cases.	Dahl 1990, p. 16; Dahl 2011, p. 16; Meck 2020, p. 5; Willey et al. 2022, pp. 23, 133–134
Climate change	Changes to timing, amounts, and intensity of rainfall events (longer dry periods, more intense storms, etc.). Northeast: total precipitation to increase, rainfall intensity increasing. Southeast: Inter-annual variability in precipitation; more droughts, more extreme rainfall, decreased precipitation overall.	Current and continuing	High confidence that overall, precipitation patterns will change, and both more intense storms and droughts will become more frequent.	Loss, degradation, or fragmentation of suitable habitat (drying, flooding, soil erosion, invasive species); behavioral changes, stress to, or loss of individuals.	Current and continuing, increasing with time	High Confidence that less rainfall will increase probability of impacts to spotted turtles. Low Confidence in impacts to turtles from other changes in precipitation timing and frequency.	Angel et al. 2018, p. 875; USFWS 2019, p. 1; Willey et al. 2022, p. 147; Dupigny-Giroux et al. 2018, p. 672; Groisman and Knight 2007, p. 1855; Wang et al. 2010, p. 1009; Carter et al. 2014, p. 399; Carter et al. 2018, p. 751;

	Threat	Timeframe	Confidence	Species Response	Timeframe	Confidence	Reference(s)
	Increased temperatures and more temperature fluctuations due to climate change	Current and continuing	High Confidence that temperatures will increase over time throughout all parts of the range.	Shift in timing/duration of behaviors (reduced fitness), physiological changes (fecundity, stress, intolerance to temperatures), skewed sex ratios.	Measurable impacts to increase with time, likely with a lag due to generational time; some impacts likely by 2050 and 2100.	High Confidence that increased temperatures will affect spotted turtles, but Low Confidence what specific impacts will be and their magnitude.	USFWS 2019, p. 1; Ward et al. 1976, p. x; Willey et al. 2022, p. 147; Yagi and Litzgus 2012, p. x; IPCC 2014, p. 10; Dupigny-Giroux et al. 2018, p. 672; Carter et al. 2014, p. 398–399
	Shift or loss of wetland habitats due to Sea Level Rise	Current and continuing	High Confidence that the sea level will rise and affect coastal ecosystems.	Habitat loss (all stages), fragmentation, and shifts.	Current and continuing, increasing with time.	High Confidence	Sweet et al. 2022, pp. 1-2; Dupigny-Giroux et a. 2018, p. 17; Willey et al. 2022, p. 8

APPENDIX C: CPUE/ABUNDANCE ESTIMATES FOR EASTERN U.S.

Independently assessing the relative size of Spotted Turtle populations across the eastern U.S.

To complement the expert-derived resiliency scores and provide additional perspective on the variation in relative abundance across the species range, with the help of our state partners (and Molly Parren, American Turtle Observatory), we summarized the standardized trapping data collected as part of the Competitive State Wildlife Grant (CSWG) effort in the eastern U.S. from Maine to Florida (Willey et al. 2022) for each of the Analytical Units (AUs) used in this SSA (Willey 2023, pers. comm).

Sampling data included all sites that were trapped using the standardized trap protocol, including both the rapid demographic assessment sites. We calculated the average catch per unit effort (CPUE) as the total number of turtles captured / the total number of trap nights across each AU. Because mean CPUE is a function of trap effort (i.e., those AUs that were more heavily trapped probably included a combination of high- and low-density sites, while those with fewer trap nights might only have only included the best-known sites, and trap success declines over time), we also calculated the maximum observed CPUE across the sites in each AU. We then plotted results to assess spatial patterns and used Analysis of Variance to compare CPUE values for AUs that were rated as low, moderate, or high resiliency.

This analysis was based on 3741 turtles trapped over 29,048 trap checks at 261 sites across 35 analytical units. Note that if a site had some traps within an AU and some outside, or if the delineated site was in an AU, but the traps were outside, all traps were counted as within the AU and included in the summary. One site in WV was split across two AUs, one in WV and one in MD; all data was paired with the WV unit. One site in VA was split across two AUs in VA; because it was the only site in either unit, it was split. Sites located outside all AUs where no turtles were captured were not included in the analysis. Five successful (turtles captured) sites that did not intersect an AU were paired with an AU based on closest/most logical unit (2 sites in GA, 1 site in MA, 2 sites in NY).

In evaluating these results, it is important to note the inherent bias in sampling results: turtles can only be detected by standardized trapping in relatively high-density populations, and therefore these results likely represent some of the best remaining populations. In addition, CPUE, while correlated with abundance estimates, is a function of detection, which varies with site, season, weather, habitat, and many other factors. However, because they used a standardized data collection approach, these results represent the best available estimates of relative abundance of Spotted Turtle populations across the sampling area and a useful complement to the expert-derived resiliency scores.

ANOVA revealed that both mean and maximum observed CPUE in high, moderate, and low resiliency AUs were significantly different from each other ($F_{2,32}=10.01$, $p<0.001$; $F_{2,32}=13.04$, $p<0.001$). Low Resiliency AUs averaged 0.05 turtles per trap night (similar to average observed CPUE across all Blanding's Turtle sites trapped in the Northeastern U.S. as part of the CSWG for that species, Willey and Jones 2014), while High Resiliency AUs averaged CPUE that was four times higher, and maximum number of turtles/trap night at High Resiliency sites was more than 10 times higher than that observed at Low Resiliency sites (Table C1; Fig. C1).

Table C1.

Resiliency Score Category	Average CPUE across all AUs in this resiliency class	Maximum CPUE observed at any site in the AU, averaged across AUs in this resiliency class
Low	0.053	0.112
Moderate	0.093	0.318
High	0.206	1.2

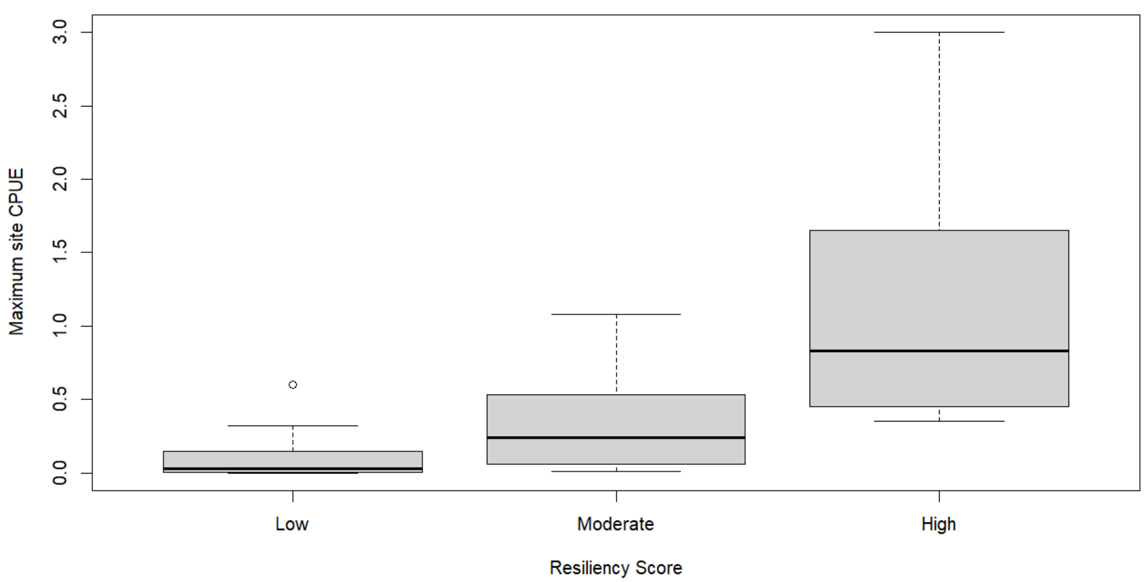

Figure C1. Distribution of the maximum observed catch per unit effort (CPUE) in each Analytical Unit, grouped by Resiliency Score

The geographic pattern of population abundance from this output is consistent with that derived from experts and suggests that resiliency scores assigned by state biologists appear consistent with results from standardized sampling across the region. Populations along the coastal plain tend to have higher CPUE (and therefore likely support more abundant and resilient populations), while those in more inland areas tend to have lower rates.

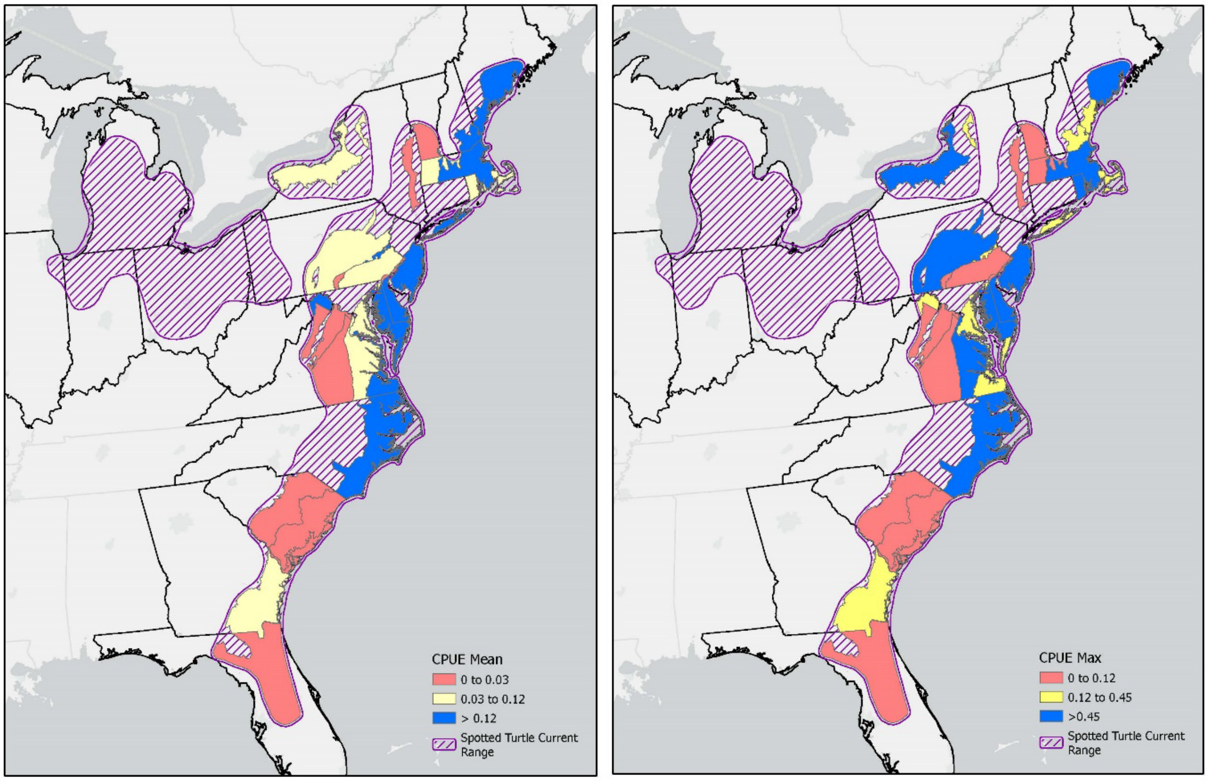

Figure C2: Maps showing the mean and max values for each analysis unit investigated in the CPUE analysis.

Table C2. Population estimates for spotted turtle sites with 5 or more turtles captured and had at least 2 recaptures (from Willey et al. 2022, pp. 272–274).

Site (State_ID)	Region	Captures	Abundance Estimate	Stderr	Upper	Lower
MA_A	Northeast	48	154.9	50.3	253.49	56.31
MA_B	Northeast	30	156.9	83.9	321.34	-7.54
MA_C	Northeast	16	26.6	6.6	39.54	13.66
MA_D	Northeast	71	105.3	10.8	126.47	84.13
MA_E	Northeast	37	110.2	38	184.68	35.72
MA_F	Northeast	33	148.8	68.1	282.28	15.32
MA_G	Northeast	34	95	32.3	158.31	31.69
MA_H	Northeast	12	40	24.8	88.61	-8.61
MA_I	Northeast	28	30.4	1.9	34.12	26.68
MA_J	Northeast	8	34.7	12.5	59.20	10.20
MA_K	Northeast	13	20.2	5.2	30.39	10.01
ME_A	Northeast	23	43.9	12.2	67.81	19.99
ME_B	Northeast	8	13.3	6	25.06	1.54

Site (State_ID)	Region	Captures	Abundance Estimate	Stderr	Upper	Lower
ME_C	Northeast	19	90.9	58.9	206.34	-24.54
ME_D	Northeast	97	152.9	14.9	182.10	123.70
ME_E	Northeast	16	60.5	37.8	134.59	-13.59
ME_F	Northeast	16	60.5	37.8	134.59	-13.59
NH_A	Northeast	24	37.6	7.4	52.10	23.10
NH_B	Northeast	12	23.9	9.3	42.13	5.67
NH_C	Northeast	24	101.9	52.7	205.19	-1.39
NH_D	Northeast	31	49.2	8.7	66.25	32.15
RI_A	Northeast	12	36.4	22	79.52	-6.72
RI_B	Northeast	18	33.5	10.7	54.47	12.53
DE_A	Mid-Atlantic	33	63.6	14.1	91.24	35.96
DE_B	Mid-Atlantic	135	193.3	13.6	219.96	166.64
DE_C	Mid-Atlantic	42	60.3	7.6	75.20	45.40
DE_D	Mid-Atlantic	11	59.4	55.1	167.40	-48.60
DE_E	Mid-Atlantic	38	48.1	4.8	57.51	38.69
DE_F	Mid-Atlantic	30	70.4	20.3	110.19	30.61
DE_G	Mid-Atlantic	6	6.8	1.2	9.15	4.45
DE_H	Mid-Atlantic	39	125.7	41.6	207.24	44.16
DE_I	Mid-Atlantic	54	259.9	97.6	451.20	68.60
DE_J	Mid-Atlantic	40	95.6	23.8	142.25	48.95
DE_K	Mid-Atlantic	33	68.5	16.3	100.45	36.55
DE_M	Mid-Atlantic	18	20.3	1.9	24.02	16.58
MD_A	Mid-Atlantic	214	308.6	17.4	342.70	274.50
MD_B	Mid-Atlantic	38	157.9	64	283.34	32.46
MD_C	Mid-Atlantic	15	29.7	10.2	49.69	9.71
MD_D	Mid-Atlantic	16	32.9	11.5	55.44	10.36
MD_E	Mid-Atlantic	16	18.7	2.2	23.01	14.39
MD_F	Mid-Atlantic	28	61.6	16.7	94.33	28.87
NJ_A	Mid-Atlantic	20	43.7	14.3	71.73	15.67
NJ_B	Mid-Atlantic	31	161.2	85.9	329.56	-7.16
NJ_C	Mid-Atlantic	12	69.6	64.9	196.80	-57.60
NY_A	Mid-Atlantic	38	121.1	40	199.50	42.70
NY_B	Mid-Atlantic	5	6.4	2	10.32	2.48
NY_C	Mid-Atlantic	36	109.1	35.7	179.07	39.13
NY_D	Mid-Atlantic	32	59.6	13.7	86.45	32.75
NY_E	Mid-Atlantic	14	25.8	9.2	43.83	7.77
NY_F	Mid-Atlantic	5	8.7	4.4	17.32	0.08
PA_A	Mid-Atlantic	37	81.4	21.1	122.76	40.04
PA_B	Mid-Atlantic	6	19.3	16.8	52.23	-13.63
PA_C	Mid-Atlantic	41	79.5	15.5	109.88	49.12
PA_D	Mid-Atlantic	15	45.2	22.6	89.50	0.90

Site (State_ID)	Region	Captures	Abundance Estimate	Stderr	Upper	Lower
PA_E	Mid-Atlantic	5	9.1	4.9	18.70	-0.50
PA_F	Mid-Atlantic	7	25.1	22.2	68.61	-18.41
FL_A	South	5	7.2	2.7	12.49	1.91
FL_B	South	32	87.9	28.2	143.17	32.63
GA_A	South	6	7.8	2.2	12.11	3.49
GA_B	South	46	47	1.1	49.16	44.84
GA_C	South	12	19.8	5.8	31.17	8.43
NC_A	South	87	414	141	690.36	137.64
NC_B	South	9	22.3	12.9	47.58	-2.98
NC_C	South	17	33.4	11.2	55.35	11.45
VA_A	South	86	174.7	24.8	223.31	126.09
VA_B	South	39	76.3	15.8	107.27	45.33
VA_C	South	5	8	3.7	15.25	0.75
VA_D	South	12	17.5	4.5	26.32	8.68
VA_E	South	18	56.7	28.2	111.97	1.43
VA_F	South	18	24.6	4.4	33.22	15.98
VA_G	South	14	47.7	29.4	105.32	-9.92
VA_H	South	71	88.3	6	100.06	76.54
VA_I	South	16	43.6	21	84.76	2.44
VA_J	South	36	212.8	114.7	437.61	-12.01
VA_K	South	21	44	13.2	69.87	18.13
VT_A	South	15	33.4	13.3	59.47	7.33
WV_A	South	20	38.8	11.2	60.75	16.85
WV_B	South	12	17.9	4.5	26.72	9.08
WV_C	South	70	382.4	134.8	646.61	118.19
WV_D	South	30	48.8	9	66.44	31.16

APPENDIX D: ADDITIONAL MOVEMENT DATA

Table D1. Upland, inter-wetland, and nesting movement distances of Spotted Turtles (*Clemmys guttata*). From Willey et al. 2022, pp. 39–40.

Author	Year	State	Description	Statistic	Distance (m)	SE (m)	Range (m)
Beaudry et al.	2007	ME		Mean, Median	208, 184	-	-
Beaudry et al.	2010a	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 Maximum	250 (m) 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		Mean,	265,	36	75-1025

Author	Year	State	Description	Statistic	Distance (m)	SE (m)	Range (m)
			Greatest distance traveled from hibernacula	Median	226		
Milam and Melvin	2001	MA	Distance between estivation site and permanent wetlands	Approx.	412	-	-
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	2010b	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