Sea turtle conservation as a blueprint for freshwater turtles in the eastern U.S.

Denise Blough
The Ohio State University School of Environment and Natural Resources

Master of Environment and Natural Resources Examination Paper

Drs. Stacey Fineran, Robert Gates, & William Peterman

April 6, 2022

Contents

Thesis statement: Increased conservation action is needed for freshwater and terrestrial turtles in the eastern U.S., which is a global hotspot for this unique suite of species. Lessons and inspiration can be drawn from sea turtle conservation in the U.S., which has helped populations rebound from extinction.

Abstract: With turtles and tortoises being one of the most threatened taxa on the planet, dire conservation action is needed. As a global hotspot for turtles — with over 85 species and subspecies — the U.S. can play a major role in curbing turtle extinction. It has already done so for its six species of sea turtles, which experienced dramatic declines over the 19th and 20th centuries due to human exploitation. Since the 1970s, the U.S. has implemented strong federal and international protections to help sea turtle populations rebound. Yet freshwater and terrestrial turtles and tortoises — the vast majority of U.S. chelonians — enjoy far less oversight, with variable state laws, areas that continue to allow harvest, and scant monitoring efforts. This paper examines gaps in management for sea turtles and freshwater turtles and tortoises in the eastern U.S. and considers how sea turtle conservation could be a model for other turtles and tortoises moving forward.

I. Overview of eastern U.S. chelonians

A. Discussion of species richness and range

Turtles and tortoises (from here on: “turtles”) are the world’s oldest living reptiles, with a fossil record extending back over 200 million years (Li et al, 2008). These tetrapod vertebrate ectotherms (order Testudines) are characterized by the bony shells that encase their bodies, which provide protection, defense and even nutritional substances (Cordero, 2016). The world’s 352 extant turtle species have a broad geographic distribution — inhabiting every continent but Antarctica, mostly in tropical and subtropical zones. They range in size from the over-7-foot-long leatherback sea turtle (*Dermochelys coriacea*) to the 10.2 cm-long Vallarta mud turtle (*Kinosternon vogti*) (Rhodin et al., 2021).

The U.S. has the highest turtle richness of any nation, with 64 species and 88 taxa (species and subspecies). Other major turtle hotspots include Mexico, Brazil, Indonesia, India and China. Most U.S. species are located in the eastern half of the country (Rhodin et al., 2021), and therefore this region will be the focus of the paper. Turtles' high presence in the eastern and particularly southeastern U.S. is reflective of their habitat requirements, which — though diverse — generally include the need for water-dominated environments like swamps, marshes, streams, lakes and oceans.

Most turtle species, both in the U.S. and globally, are aquatic or semi-aquatic and depend on freshwater ecosystems. Terrestrial turtles or tortoises (family Testudinidae) are the second largest category at about 53 species globally, though only three tortoise species are found in the U.S. There are only seven species of marine turtles (families Cheloniidae and Dermochelyidae) worldwide (Rhodin et al., 2021).

1. Eastern U.S. sea turtles

Six of the world's seven sea turtle species nest along U.S. coasts. Five of these — loggerhead (*Caretta caretta*), green (*Chelonia mydas*), Kemp's ridley (*Lepidochelys kempii*), hawksbill (*Eretmochelys imbricata*) and leatherback (*Dermochelys* coriacea) sea turtles — can be found along the Atlantic and Gulf Coasts, with green, loggerhead and leatherback turtles being the most abundant species (Allison et al., 2010).

Sea turtles migrate long distances between foraging, breeding and nesting grounds — thousands of miles per year across multiple oceans — over their lives, making it somewhat challenging to calculate population sizes (Bennett, 2018). Estimates suggest these five turtle species have a combined global population of around 1,820,000 individuals with a lower bound of 502,000 and an upper bound of 3,962,000 (Sifuentes-Romero et al., 2020). These numbers pale in comparison to historic population estimates, which were thought to be at least 10 times as high before human exploration and settlement, after which sea turtles were harvested by the thousands for meat, eggs and materials (Carr, 1982; Sifuentes-Romero et al., 2020). Fortunately, thanks to multiple factors, U.S. populations have generally increased over the past decade (Allison et al., 2010).

2. Eastern U.S. freshwater / terrestrial turtles

Approximately 90% of U.S. turtles (58/64) are non-marine turtles, and most of them can be found around the Gulf and southeast Atlantic coasts. Alabama, Florida, Georgia, Louisiana, Texas and Mississippi are particularly noteworthy for their number of native turtle species, with each state having 20—30 endemics (Rhodin & van Dijk, 2010). These include the gopher tortoise (*Gopherus polyphemus*), a terrestrial turtle and ecosystem engineer whose burrows provide refuge for over 300 other wildlife species (Enge et al., 2006); the ringed map turtle (*Graptemys oculifera*), a freshwater turtle restricted to the Pearl River system of Mississippi and Louisiana (Bonasia, 2014); and the Gulf Coast box turtle (*Terrapene carolina major)*, the largest living subspecies of box turtle (Willey, 2001).

Temperate eastern states also host considerable turtle diversity, such as New York, Maryland, Pennsylvania and Ohio, which have species like the Blanding's turtle (*Emydoidea blandingii*), a highly mobile freshwater species that prefers wetland and upland habitats (Grey et al., 2015), and the wood turtle (*Glyptemys insculpta*), which thrive in complex habitat mosaics of streams, riparian woods, thickets and open grassy areas (Harding & Armitage, 2000). Population estimates for most eastern U.S. turtles are sparse, and evidence suggests that many turtle populations have experienced major range declines due to habitat loss, degradation and fragmentation (Rhodin & van Dijk, 2010; Rhodin et al., 2021).

B. Ecological roles/importance

The diversity of eastern U.S. turtles in diet, habitat and behavior means these animals also play diverse roles in their respective ecosystems. Turtles are typically capable of achieving relatively high biomasses in their environments, and they can therefore have important effects on energy flow, nutrient and mineral cycling, seed dispersal and germination, trophic interactions, soil dynamics and more (Lovich et al., 2018; Stanford et al., 2020).

1. Sea turtles

A study led by Bouchard and Bjorndal (2000) on nesting loggerhead sea turtles in Florida illustrates the remarkable effects these species can have on energy and nutrient transfer in ocean and coastline ecosystems. They bring important nutrients like phosphorus and nitrogen to the shore, help maintain dune systems and vegetation, provide energy for avian and mammalian predators, and eventually contribute energy back to the sea through their offspring.

Another example is seen in green sea turtles, which are critical to promoting the health of seagrass beds through their foraging habits. Without green sea turtle foraging, dead seagrass accumulates underwater, increasing nitrogen levels and decreasing productivity throughout the food web (Jackson, 2001). These turtles appear to have a specific, strategic foraging strategy that maximizes seagrass productivity and benefits the entire ecosystem, including the 100+ other marine fauna that feed on seagrass beds (Moran & Bjorndal, 2005).

Leatherback sea turtles primarily feed on jellyfish — up to 440 pounds each day. Jellyfish would proliferate in their absence, a trend that could be compounded by the decline of other ocean predators and set off trophic cascades that alter the entire community structure (Wilson et al., 2005). Loggerhead sea turtles forage along the ocean floor when searching for food, and this movement has beneficial effects for the sediment such as reducing sand compaction and distributing nutrients, which in turn benefits benthic organisms. Sea turtles also carry around organisms like algae, epibionts and barnacles on their bodies, which serve as food for fish and shrimp that establish "cleaning stations" for the turtles (Wilson et al., 2005).

2. Freshwater / terrestrial turtles

Herbivorous terrestrial turtles like the gopher tortoise play major roles in their environments through grazing and digging burrows. As mentioned, these burrows provide habitat for more than 350 other species, including mammals, invertebrates, amphibians and other reptiles (FWC, n.d.). North American freshwater turtles are also known to absorb certain pollutants and have served as indicators of mercury levels in the environment (Lovich et al., 2018).

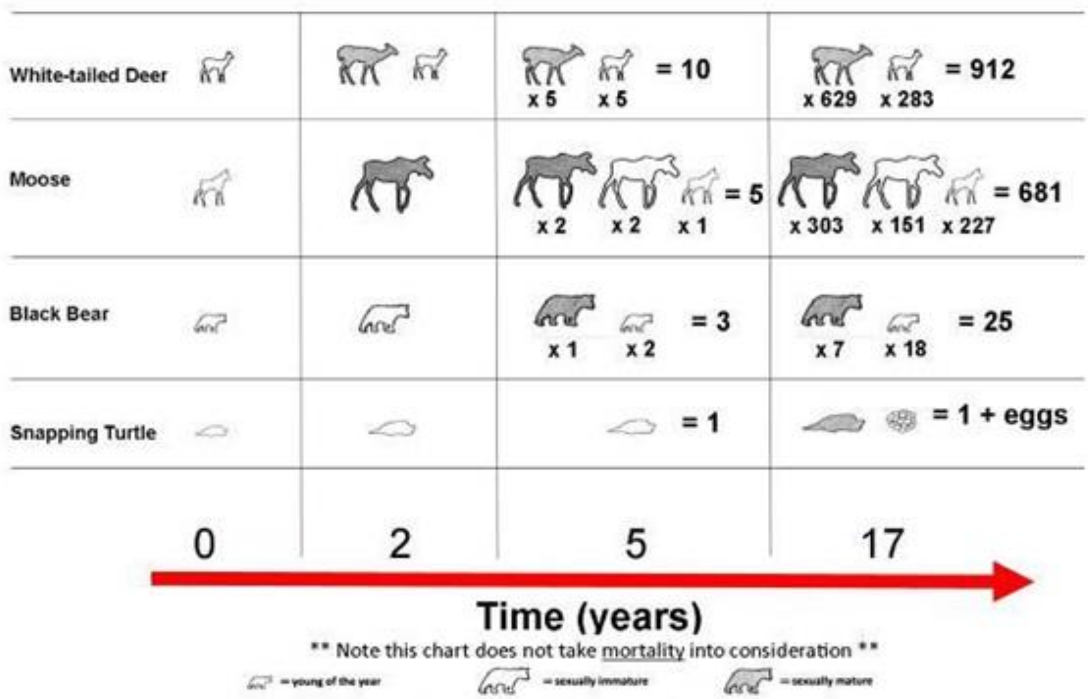
Silliman and Bertess (2002) found that diamondback terrapins (*Malaclemys terrapin*) are crucial to regulating periwinkle snails, which can degrade salt marshes without predator control. Turtles can also help disperse seeds, such as eastern box turtles (*Terrapene carolina*) and mayapple seeds (Rust & Roth, 1981). Other freshwater species like the common snapping turtle (*Chelydra serpentina)* and slider turtles like the pond slider (*Trachemys scripta*) benefit aquatic systems through providing nutrients and increasing the health and complexity of food webs (Lovich et al., 2018).

C. Life history traits that present management challenges

The long-lived nature of turtles means populations are sensitive to removal. Turtles take a long time to reach sexual maturity (up to 30-plus years in some species, such as the green sea turtle). This is because turtles live a long time — even smaller freshwater turtles like Blanding's turtles (*Emydoidea blandingii*) and eastern box turtles (*Terrapene carolina carolina)* can live to be over 80 years old — which can make it a challenge to understand turtles without long-term studies (Cross, 2021).

Per capita reproductive output is also limited given most turtles only lay eggs once per year, if that, and many offspring never make it to adulthood due to various factors including nest predation (Cross, 2021; Bennett & Loda, 2020). This means that a sufficient number of individuals need to live long enough to reproduce and help sustain the population, and that even slight reductions can have relatively large impacts on population size. These dynamics may also reduce the ability of wildlife managers to notice turtle declines, because populations may appear healthy even when no individuals are actively reproducing (Cross, 2021).

Figure: A comparison of reproductive potential among big-game species in Ontario. From Ontario Turtle Conservation Center.



II. Conservation need

More than 51% of living testudines species are classified as being at risk of extinction by the International Union for Conservation of Nature, making them the most threatened group of vertebrate animals following primates (Rhodin et al., 2021). They are threatened by habitat loss, degradation and fragmentation; the wildlife trade; bycatch; plastic and debris; pollution; climate change; and disease, among others (Kimbrough, 2020).

A. Current threats to sea turtles

All six sea turtle species found in the U.S. are listed as endangered or threatened under the Endangered Species Act (1973).

The largest threats facing sea turtles echo those faced by other marine wildlife, including ingestion of and entanglement in plastic waste and other ocean debris; ocean pollution; and bycatch and entanglement in fishing gear. Other key challenges include habitat loss and degradation of nesting beaches, light disorientation, and disease (Griffin et al., 2010).

1. Anthropogenic

In Donlan et al. (2010)'s survey of 244 sea turtle experts, fisheries bycatch and coastal development were consistently ranked among the top hazards to sea turtles in the Atlantic. Other leading conservation issues include plastic pollution, which impacts a vast range of marine species at every trophic level (NOAA, 2014).

<u>Bycatch</u>

Entanglement and capture in active and abandoned fishing gear poses a huge threat to sea turtles in the mid-Atlantic and southeast Atlantic. The most recent bycatch report from the U.S. National Atmospheric and Oceanic Administration estimates nearly 2,000 turtles were impacted by bycatch in these combined regions in 2015, despite continual efforts to reduce accidental sea turtle capture through Turtle Excluder Devices and associated regulations (Benaka et al., 2019). Trawls, longlines, driftnets and gillnets are among the most problematic fishing equipment types for bycatch-induced sea turtle mortality (WWF, 2017).

<u>Plastic/Other debris</u>

In addition to fishing gear, sea turtles are also highly susceptible to ingestion and entanglement of other anthropogenic debris — chiefly plastic debris. Young sea turtles, in particular, tend to travel across the sea on ocean currents to convergence zones, which is where debris also aggregates (Duncan et al., 2011; NOAA, 2014). These turtles may mistake plastic for prey, accidentally ingest plastic that is nearby or attached to actual prey, or use plastic items as cover objects from predators and thereby end up trapped or entangled (Nelms et al., 2016).

Wilcox et al. (2018)'s analysis of over 1,000 sea turtles found that they have a 50% mortality rate after ingesting only 14 pieces of plastic. Even just one piece of plastic was linked with a 22% probability of dying. Another study of 102 sea turtles from the Atlantic, Mediterranean and Pacific Oceans discovered microplastics in the gut of every single turtle (Duncan et al., 2018). Plastic debris also poses additional obstacles to both nesting females and hatchlings on nesting beaches (Nelms et al., 2016).

Habitat degradation from human use and development

Open, sloping beaches largely free of human influence are critical habitats for nesting sea turtles. Human development on U.S. coasts has led to the loss and degradation of these habitats through anthropogenic impacts including:

- Manmade erosion-prevention structures, like seawalls and jetties, which may prevent nesting turtles from reaching the high tide line, where their eggs will not be flooded (Fuentes et al., 2016).
- Artificial lights that disorient baby sea turtles, who find their way to the ocean by the reflected light of the moon (Witherington, 1992; Mannion, 2020).
- Beach compaction and nourishment, which alter the natural structure of sands and can adversely impact nest-site selection, incubation temperature and nest moisture content (STC, n.d.).

With population growth and development along U.S. coasts at record highs, (NOAA, 2018; Cohen, 2018), these ecological issues are increasingly important to consider.

2. Natural (predation, climate change)

Sea turtle eggs are vulnerable to scavenging predators like coyotes, raccoons, shorebirds and crabs, which is why many conservation efforts include placing fencing and screens around nests. An analysis of 16 sea turtle nesting beaches in Florida found that predation was among the top two sources of egg and hatchling mortality, with mammalian predation reducing emergence success up to 39% in loggerhead turtle nests and 32% in green turtle nests (Brost et al., 2015). As new hatchlings and juveniles, turtles are additionally subject to marine predators including sharks, dolphins and large fish (Kennedy, 2019). And, while illegal, poaching of sea turtle eggs by humans still occurs in the U.S. (DOJ, 2021).

Climate change is threatening sea turtles in multiple interacting ways. Firstly, sex determination in sea turtles is temperature-dependent, with cooler egg incubation temperatures producing males and higher incubation temperatures producing females. Hawkes et al. (2007) found that loggerhead turtles nesting in the eastern U.S. would experience sex ratios highly skewed toward females under scenarios of global warming, the most extreme of which would cause 100% female hatchling production and lethally high incubation temperatures. Climate change is also expected to affect species distribution (Patel et al., 2021; Fuentes et al., 2020), foraging success and breeding phenology (Lettrich et al., 2020; Hawkes et al., 2009). Sea level rise, warmer temperatures, more extreme precipitation events and ocean acidification as modeled by the Intergovernmental Panel on Climate Change will put further pressure on sea turtle populations (Lettrich et al., 2020; IPCC, 2022), potentially causing increased pre-emergence mortality in more southern U.S. Atlantic nesting beaches (Montero et al., 2018). Continually rising and more frequent extreme sea levels, in particular, are expected to perpetuate beach erosion and decrease available nesting habitat for sea turtles and force them to nest closer to the water line (Lyons et al., 2020).

B. Current threats to eastern U.S. freshwater/terrestrial turtles

Like sea turtles, freshwater and terrestrial turtles in the eastern U.S. are facing major pressures from humans, and many species are thought to be declining (Stanford et al., 2020; Rhodin et al., 2021). The IUCN Tortoise and Freshwater Turtle Specialist Group's latest report finds that nearly 56% of extant turtle species are classified as globally endangered, threatened or vulnerable, with over 40 new species becoming listed as threatened since 2009 (Rhodin et al., 2021; Rhodin et al., 2009). The most severely endangered freshwater and terrestrial turtles are found in Asia, where turtles have long been used for food and traditional medicine (Stanford et al., 2018). In the eastern U.S., turtles are chiefly threatened by habitat loss and degradation, though there is increasing concern as the U.S. begins to export more of its own turtles to Asia to supply increasing demand (Mali et al., 2014). The international pet trade is another continually growing conservation concern for turtles (Stanford et al., 2020).

1. Wild-caught turtle trade

Scientific evidence suggests freshwater and terrestrial turtles are not viable candidates for sustainable harvest programs, given the life history traits discussed earlier that constrain population growth rates (Rachmansah et al., 2020). Due to this, overexploitation of turtles for food, pets and traditional medicine is the main threat facing the world's most endangered freshwater and terrestrial turtle species, most of which are found in Asia, where consumptive use of turtles is most prevalent (Stanford et al., 2018). With declines in Asian turtle populations, demand is increasingly being met through U.S. imports (Mali et al., 2014). More than 2 million wild-caught turtles were traded in global markets between 1990-2010, with the U.S. becoming an increasingly prevalent exporter over this time period, according to a 2020 technical work group led by CITES and the Association of Fish and Wildlife Agencies (AFWA & CITES, 2020). This work group also found that over 60% of the 18+ million total turtles (captive and wild) exported from the U.S. between 2013—2018 went to Asian markets.

The global turtle trade occurs both legally and illegally, with the latter being the biggest concern and often involving "extensive informal networks of trappers, hunters and middlemen" (CITES Conf. 11.9). For example, a multi-year turtle scheme halted by the U.S. government in 2020 involved $2.2 million, five middlemen, PayPal, Facebook, and 1,500 endangered turtles from eastern U.S. wetlands (eastern, Florida and Gulf Coast box turtles; spotted turtles and wood turtles), which were to be sold on the Asian pet black market (Fieseler, 2020). It took an undercover U.S. Fish and Wildlife Service agent posing as one of the perpetrator's middlemen to eventually stop the operation. In 2018, turtle poachers in Florida sold more than 4,000 native turtles, including striped mud turtles and diamondback terrapins, in a six-month time period (Bennett Williams, 2018).

On the legal side, eight U.S. states still allow for unlimited or nearly unlimited harvesting (5+ individuals per day) of one or more native turtle species — all in the eastern half of the U.S., where turtle richness is highest. These include Arkansas, Delaware, Louisiana, Maryland, Minnesota, Ohio, Oklahoma and Tennessee (Bennett & Loda, 2020).

2. Other threats

a. Habitat loss/fragmentation

Many eastern U.S. freshwater turtles exhibit complex habitat needs, moving across different habitat types — i.e. upland, wetland, forest — throughout the year (Quesnelle et al., 2013; Joyal et al., 2002). Wetlands are often a key component of these habitat mosaics, and the decline of wetlands across much of the country (including up to 90% loss in some areas) has left many turtles without the habitat requirements they need to thrive (Gibbons et al., 2000). Current wetland conservation efforts are often limited to wetlands themselves without considering adjacent upland buffer zones and landscape connectivity, which would benefit turtles and other wildlife, as well as protect water quality (Attum et al., 2009).

The wood turtle (*Glyptemys insculpta*) is one such turtle that moves between streams, wetlands and riparian forests. A recent study by Willey et al. (2022) found that around 58% of potentially suitable habitat for this northeastern U.S. species is degraded due to land-use. This kind of degradation is especially impactful given that wood turtles — and many other freshwater turtles — may travel large distances during different life and seasonal stages (Patrick & Gibbs, 2010). Wood turtles, specifically, were found to have ranges of up to 15 km or more in a national forest in Virginia, where they moved between different streams and valleys (Jones et al., 2018; Akre, 2020).

Given this habitat complexity, it is likely just as important to restore and preserve wetlands as it is to maintain forests and landscape connectivity (Quesnelle et al., 2013; Joyal et al., 2002; Buchanan et al., 2018). When landscapes are fragmented, road mortality may become a large driver of freshwater turtle population decline (Langen et al., 2012). In painted turtles (*Chrysmemys picta*) and snapping turtles (*Chelydra serpentina*), Steen and Gibbs (2004) found that turtle road mortality in a fragmented landscape resulted in a male-sex population bias, likely due to a disproportionate number of females being hit by cars during nesting migrations that often take place during traffic rush hours at dawn and dusk. Other life cycle stages include migrations that can leave turtles susceptible to road mortality, including juvenile dispersal and males in search of mates (Steen & Gibbs, 2004).

Road mortality has been a particular challenge for terrapin species like the diamondback terrapin (*Malaclemys terrapin*), which are specialized to brackish waters and live in salt marshes along the eastern Atlantic and Gulf coasts. Female diamondback terrapins prefer nesting in open, elevated habitats, which often brings them into contact with major roadways, which is why many conservation efforts have included the construction of road culverts and strategically placed artificial nest boxes (Crawford et al., 2017; Quinn et al., 2015).

For some species, such as for the federally threatened gopher tortoise (*Gopherus polyphemus*), habitat loss alone is the main threat. Gopher tortoises rely on longleaf pine forest ecosystems in the southeastern U.S., many of which have unfortunately been lost or replaced by loblolly or slash pine plantations for commercial harvest (Van Lear et al., 2005).

b. Depredation

Urban predators like racoons (*Procyon lotor*) or coyotes (*Canis latrans*) also threaten the persistence of freshwater and terrestrial turtles (Stanford et al., 2020; Schwanz et al., 2010). In an urban area in Illinois, Strickland et al. (2010) found that 34% of simulated painted turtle (*Chrysemys picta*) nests were depredated. Riley & Litzgus (2014) found that depredation of snapping turtle (*Chelydra serpentina*) and midland painted turtle (*Chrysemys picta marginata*) nests occurred throughout the incubation period, with peaks happening during later stages, potentially coinciding with hatchling emergence.

c. Climate change

As with sea turtles, freshwater and terrestrial turtle clutches exhibit temperature-dependent sex determination. Therefore, a major concern with climate change is that increased incubation temperatures could skew sex ratios by leading to fewer male hatchlings, which are determined under cooler temperatures. With less males to breed with females, population growth would likely be slowed (Stanford et al., 2020; Butler, 2019).

In addition, Janzen et al. (2018)'s review of long-term nesting trends in six genera of eastern U.S. turtles (*Chelydra, Chrysemys, Kinosternon, Malaclemys,* *Sternotherus* and *Trachemys*) found that some populations are nesting earlier in the season with warmer climates. This sort of altered phenology could impact hatchlings in these species, which typically overwinter in the nest after emerging. Hatching earlier may lengthen the amount of time they must stay in the nest without food, and warmer temperatures may also impact development speed.

Warming temperatures may also shift some species' climatic ranges northward as turtles attempt to maintain their thermal niches, affecting how much suitable habitat is available (Ihlow et al., 2012. Climate models by Hamilton et al. (2018) found that by the 2050s, Blanding's turtles in Wisconsin would have almost no suitable habitat under high CO_2-emissions models. In a review of climate change impacts on chelonians, Butler (2019) predicted that differences in community structure due to climate change-induced range shifts of other species (Parmesan & Yohe, 2003) could also affect turtle resource and prey availability in the future.

III. Legal/Institutional overview

A. Sea turtles

Since human harvesting for more than a century led to mass sea turtle declines (Carr, 1982; McClanachan et al., 2006), many laws and regulations have been enacted to protect sea turtles and help populations rebound.

1. Federal (ESA)

The most important legal framework — and the one that provides the most protections for sea turtles in the U.S. — is the Endangered Species Act of 1973 (ESA), which mandates federal protections for listed species. The U.S. Fish and Wildlife Service (USFWS) within the U.S. Department of the Interior and the National Marine Fisheries Service (NOAA Fisheries) within the U.S. Department of Commerce's National Oceanic and Atmospheric Administration are jointly responsible for implementing ESA regulations for sea turtles.

The five sea turtle species occurring in the eastern U.S. are all listed as endangered under the ESA, with some distinct population segments (DPSs) of green and loggerhead turtles listed as "threatened," meaning the species is likely to become endangered within the foreseeable future, and therefore have slightly lower levels of protections than “endangered” species.

USFWS and NOAA are responsible for sea turtle management activities including:

- Regular monitoring and classification
- Designating critical habitat, which can be protected from human development/alteration
- Developing/Implementing recovery plans
- Overseeing incidental take permits
- Consulting on actions that may affect sea turtles or their habitat
- Providing grants and authorizing research for species conservation
- Entering into multilateral agreements to encourage conservation efforts
- Investigating ESA violations

Outside the ESA framework, NOAA Fisheries has played a large role in protecting sea turtles. In 1980, the agency set up a regional system in the southeastern U.S. called the Sea Turtle Stranding and Salvage Network, which is a collaborative effort between federal, state and private partners to document stranded (dead or alive) sea turtles to inform conservation management. Additionally, NOAA Fisheries has championed regulations on Turtle Excluder Devices (TEDs) for fishing gear, which have been key in curbing bycatch mortality. Currently, TEDs are required in trawl fisheries targeting shrimp and summer flounder in the South Atlantic and Gulf of Mexico. Other related regulations include “Protected Species Observers,” which are professionals trained by NOAA Fisheries to monitor fisheries’ interactions with sea turtles and ensure regulatory compliance, which in turn helps the agency gather more data about bycatch.

2. International

Because of sea turtles’ global distribution, international laws have been key to their conservation. International agreements include the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 1973), to which 183 countries are party. Sea turtles are listed under Appendix 1, which prohibits commercial trade of sea turtles among CITES parties. USFWS is responsible for carrying out CITES provisions and is supported in these efforts by NOAA Fisheries.

The Inter-American Convention for the Protection and Conservation of Sea Turtles, formed in 2001 under the United Nations Convention on the Law of the Sea, is an agreement of 15 American nations to promote sea turtle research, protection, conservation and education. Progress and new work toward these goals are discussed at biannual Conferences of the Parties. Additionally, the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and Southeast Asia of 2001 further protects negative impacts to sea turtles through the implementation of a Conservation and Management Plan among signatory states (including the U.S.). The U.S. also adheres to the Food and Agriculture Organization of the United Nations' 2004 Guidelines to Reduce Sea Turtle Mortality in Fishing Operations (FAO, 2009).

3. State/Local (i.e. lighting ordinances)

Complementing large legal frameworks are local laws, such as lighting ordinances requiring coastal residents to use certain types of light bulbs or prohibiting beach-front lighting to reduce disorientation among nesting turtles and their offspring. In South Carolina, areas such as Georgetown County, and the Isle of Palms have local laws prohibiting artificial lights from illuminating beach areas, and the state has similar provisions to help reduce sea turtle hazards on nesting beaches (SCDNR, 2008). Similar laws can be found in coastal Florida towns and counties (FWC, n.d.).

These many international, national, state and local regulatory components work in tandem to conserve sea turtle populations.

B. Freshwater/terrestrial turtles

Freshwater and terrestrial turtles in the eastern U.S. generally have far less legal oversight than sea turtles.

1. Federal

Only two freshwater turtle species are listed as endangered under the ESA, one of which occurs in the eastern U.S. — the Plymouth red-bellied cooter (*Pseudemys rubriventris* *bangsi*). Seven additional freshwater turtles are listed as ESA threatened, six of which occur in the eastern U.S. Management of these species falls to the USFWS with the support of relevant states. Like ESA-listed sea turtles, these species have individual species recovery plans and protection from human harvest, among other protections. Non-ESA-listed freshwater and terrestrial turtle species are chiefly managed by states.

The Lacey Act (1900) prohibits trade in U.S. turtles and other wildlife species that have been illegally taken, possessed, transported or sold — thereby underscoring state, international and federal laws through the addition of a separate offense to these crimes. The Lacey Act has allowed for improved enforcement of turtle trafficking crimes (TWS, 2014).

2. State

State laws are highly variable, with a few states, like South Carolina, banning all commercial trade of native freshwater/terrestrial turtles. South Dakota is somewhere in between, placing a possession limit on four individual turtles per species per season, and banning trade. On the other end of the spectrum are states like Ohio, where anyone with a fishing license can trap and take an unlimited number of common snapping (*Chelydra serpentina*), spiny softshell (*Apalone spinifera*) and smooth softshell (*Apalone mutica*) turtles from July 1 through Dec. 31, as long as the turtles have a straight-line carapace 11 or more inches. Furthermore, there is no limit on commercial trade except for the export of live turtles, which requires a commercial or noncommercial propagating license. Along with Ohio, seven other U.S. states continue to allow unlimited harvesting for one or more turtle species (Bennett & Loda, 2020).

3. International (CITES)

In addition, eastern U.S. turtle species are increasingly regulated under CITES, with over 30 species currently listed, mostly under Appendix III, which requires special documentation to transport or trade these species.

IV. Monitoring, oversight and research efforts

A. Sea turtles

Marine turtles are notoriously difficult to study due to their long migrations across many miles of ocean, but ongoing monitoring and assessment from the ESA and other legal frameworks, as well as ever-increasing satellite tracking efforts, have given scientists valuable insight into sea turtle ecology.

A growing body of academic research has used satellite telemetry to gather information about sea turtle abundance (Weber et al., 2013); migration routes (Varo-Cruz et al., 2013; Mansfield et al., 2017); habitat use at different life stages (Mansfield et al., 2021; Pajuelo et al., 2012), and anthropogenic threats such as bycatch (Mettler et al., 2020; Cuevas et al., 2018). Satellite tracking has even been used to examine projected range shifts in loggerhead habitat due to climate change (Patel et al., 2021).

Conservation organizations have also played a large role in sea turtle monitoring, with nonprofits running large-scale operations like the Sea Turtle Migration-Tracking Education Program (Sea Turtle Conservancy) or the World Wildlife Fund's Sea Turtle Satellite Tracking Initiative.

In summary, the scope of monitoring data for these animals is vast. A review by Hays & Hawkes (2018) estimates that in total, sea turtle satellite tracking data covers all seven sea turtle species and all global oceans where they are known to occur. "There are no comparable tracking efforts across all species in a family for any other marine vertebrate that we are aware of," the authors conclude. However, there remain opportunities to better integrate this information into conservation decisions (Jeffers & Godley, 2016).

B. Freshwater and terrestrial turtles

Given the varied management oversight of freshwater and terrestrial turtles in the eastern U.S., monitoring efforts vary by state and by species.

1. Lack of widespread state-level monitoring

Population abundance and distribution estimates for freshwater and terrestrial tortoises are mostly available for species that are state or federally protected, or for those that have been the subject of ongoing research or regional conservation plans, like the wood turtle (Jones et al., 2018) or Blanding's turtle (Marchand et al., 2017) in the northeast.

Going back to our case study of Ohio, where citizens can take unlimited numbers of snapping, spiny and smooth softshell turtles from July 1—Dec. 31, there is no monitoring other than requiring harvesters to maintain records of the number, location and sizes of the turtles they collect (OAC Rule 1501:31-25-04; Ohio Rev. Code §1531.02). About 10,000 Ohioans reported harvesting turtles between 2009-2014, which was the only data I could find (Adkins et al., 2017). In addition, Adkins et al. (2017) found that distribution estimates for most Ohio turtle species are more than 50 years old.

Public records obtained by the Center for Biological Diversity found high levels of turtle harvesting in other states with weak protections, such as Arkansas, where an average of 94,000 turtles per year were reported harvested from the wild between 2004-2017 (actual numbers are higher given that less than 50% of harvesters reported their catch), and Oklahoma, where an average of 50,000 wild turtles were collected per year between 1994-2014 (Bennett & Loda, 2020). The center's report concluded that stricter regulations, monitoring, and harvest reporting requirements in these states are necessary to protect turtle populations from further declines and overuse in legal and illegal markets.

2. Conservation initiatives and citizen science

Conservation initiatives and citizen science have helped fill some gaps in state-level turtle monitoring.

a. Conservation groups

One such effort is the Collaborative to Combat the Illegal Trade in in Turtles (CCITT), formed in 2018 by the conservation organization Partners in Amphibian and Reptile Conservation (PARC). The collaborative connects state, federal and tribal agency personnel with scientists, academic researchers and conservation organizations with the goal of fighting illegal turtle trafficking and coordinating state regulations to better address conservation needs. Large conservation groups like PARC and the Turtle Survival Alliance provide avenues for freshwater turtle scientists and managers to pool their collective knowledge and resources to improve conservation research and initiatives.

b. Citizen science

Citizen science has been another invaluable tool for monitoring freshwater and terrestrial turtle abundance in the eastern United States. Online reporting tools like iNaturalist and

HerpMapper allow anyone to upload photos and locations of turtle species they encounter, and this data further supports research and monitoring efforts. Turtle researchers have also enlisted citizen scientists into their projects to help offset data collection costs. In a Blanding's turtle assessment in Michigan, local citizen scientists helped researchers conduct visual surveys through photography (Cross, 2021).

V. Bigger picture/paths forward

Despite the efforts mentioned above, freshwater and terrestrial turtles are still declining, as detailed in the beginning sections of this paper.

A. Freshwater and terrestrial turtles need our help

Considering the number of turtle species in decline; the gaps in monitoring, protection and research between sea turtles and freshwater and terrestrial turtles; the growing illegal turtle trade; and the U.S.'s uniquely high turtle biodiversity, it is evident that more can be done to help non-marine turtles in the eastern U.S.

One obvious such place to begin might be reviewing harvesting regulations. For the eight states that still have unlimited turtle bag limits for at least one species, the common snapping turtle (*Chelydra serpentina*) is commonly one of them. Yet a study of snapping turtles in Michigan found that removing just 10% of adults could reduce populations by 50% in just 15 years (Congdon et al., 1994). The study concluded that commercial harvests of snapping turtles for pet, meat and traditional medicine markets "will certainly cause substantial population declines. This is concerning considering that snapping turtle exports may be increasing. Nationwide, more than 200,000 wild-caught snapping turtles were exported from the U.S. to Asia in both 2012 and 2014, up from just 50,000 in years past, according to a study in the *Journal for Nature Conservation* (Colteaux & Johnson, 2017).

In Missouri, Zimmer-Shaffer et al. (2014) found that harvesting just 2.3% of local populations of common snapping, smooth softshell *(Apalone mutica*) and spiny softshell (*Apalone spinifera*) turtles nearly always led to population declines. "Elasticity analyses demonstrated that adults, which are the most vulnerable to commercial harvest, were the most important segment of the population demographically. These results corroborate the findings of other studies, which indicate that even low annual harvest rates may have detrimental effects on the long-term sustainability of turtle populations at localized scales," the authors stated.

Given the many other threats non-marine turtles in the eastern U.S. are facing — from climate change to illegal collection to habitat loss — it may be worth questioning the sustainability of legal turtle harvesting.

B. Sea turtles as a conservation model

Being an iconic, cosmopolitan group of species, sea turtles have sustained large movements of conservation support from public, private and nonprofit avenues in the eastern U.S. since the 1970s. It is because of this support, as well as the many legal protections safeguarding sea turtles, that their populations have been able to persist (and in many cases, increase) in the face of many compounding threats.

To assess how ESA listing has influenced sea turtle population recovery, Valdiva et al. (2019) calculated population trends for eight sea turtle populations since the time of species listing. Six of these populations have significantly increased, while the others have remained stable. Unlike the marine mammal populations examined in the study, there were no declines in any of the sea turtle populations post-ESA listing. In Florida, leatherback sea turtle nests have risen from about 50 in 1989 to over 400 in 2021, and green sea turtle nest numbers have risen from less than 300 in 1989 to 25,000 in 2021, according to the Florida Fish and Wildlife Conservation Commission's annual Index Nesting Beach Survey.

Furthermore, Mazaris et al. (2017) analyzed 299 time series of annual sea turtle nesting abundance and found increasing trends over the past decade in all observed Atlantic populations, other than for olive ridleys along the east African coast. The authors suggest that various interacting factors are responsible for general sea turtle stability, including harvesting bans; efforts to reduce bycatch through law and technology; protection of nests from predators; and local conservation initiatives.

While it's unfeasible to think that every conservation method used for sea turtles could be used for the (many more numerous) freshwater and terrestrial turtle species in the eastern U.S., these strategies certainly serve as a starting point for inspiration. Sea turtles also differ from other turtles in their global ecology, and management for freshwater and terrestrial turtles is often confined to comparably localized scales. Despite these differences, marine turtles have shown us how, even when populations are constrained by life history traits, anthropogenic impacts and environmental threats, implementing key measures such as protection from take, robust monitoring and cross-sector conservation collaborations can save turtles from the brink of extinction.

C. Closing the gap/promising case studies for freshwater/terrestrial turtles

I wanted to end this paper with some encouraging, innovative examples of ways people are helping native freshwater and terrestrial turtles.

1. Wisconsin road-crossing reports, turtle culverts and fencing

In Wisconsin, the state Departments of Natural Resources and Transportation teamed up to compile and manage public reports of turtle road crossings. Since 2012, the initiative has gathered over 7,500 reports, informing the construction of two highway culverts and associated fencing to protect turtles crossing the road (Badje, 2021). The Wisconsin DNR also provides outreach materials including a video and instructions on how to build a turtle nest cage for those who discover turtle eggs on their property.

2. Tracking box turtles in North Carolina

Like many states, North Carolina only has limited protections for turtles, despite a lack of recent population data. Citizens concerned about the future of eastern box turtles (*Terrapene carolina carolina*), which can be legally harvested in the state, began a program to track individual box turtles through citizen science data, radio telemetry and photos of turtle shells, which can be used to identify individuals since each pattern is unique (Rapp Learn, 2015).

3. Environmental DNA to estimate turtle abundance emerging as a cost-effective tool

Animals shed small amounts of genetic material into their surrounding environment — "environmental DNA" — which can be used to detect species' presence without visual surveys or physical capture (Davy et al., 2015). Recently, eDNA methods have proven useful in estimating the abundance of freshwater turtle species, specifically through detecting eDNA in water samples, while also saving time and resources (Akre, 2020). For example, Kessler et al. (2019) analyzed the presence of alligator snapping turtles in an Illinois river system using eDNA, which proved detectable up to a kilometer downstream from where turtles actually were. Grieco (2018) used eDNA to locate spotted turtle habitats in Maryland, and Akre et al. (2019) showed that eDNA was just as effective as visual encounter surveys in estimating the abundance of wood turtles in Virginia.

4. South Carolina bans commercial turtle trade

Lastly, South Carolina passed a bill in 2020 that halts the commercial trade of the state's native turtles — an important step in the fight to protect threatened turtles and keep common species common (Center for Biological Diversity, 2020).

VI. Conclusion

As one of the oldest creatures on the planet, turtles have been through their fair share of conservation challenges — but without more help, many turtle species could become locally extirpated or extinct. With the growing global trade in non-marine turtles, and the United States' growing role in fueling it, new actions must be taken to preserve eastern U.S. turtle biodiversity. The region's successes in marine turtle protection provide both a source of hope and a blueprint for moving forward.

Government and agency officials, land managers, and scientists should consider:

- Banning all commercial and recreational turtle harvesting unless population monitoring data and peer-reviewed scientific research indicate there can be sustainable harvest levels
- Using innovative methods such as citizen science and eDNA to reduce funding needs for gathering such data
- Include wetland-adjacent areas in addition to wetlands when implementing wetland protection and restoration programs when possible, and protect and manage these habitat mosaics with turtles in mind
- Enhance communication between law enforcement officials, wildlife biologists, state agencies, and academic researchers regarding illegal turtle trafficking and turtle conservation
- Increase public awareness and outreach about threats to turtles
- Empower and promote citizen science initiatives that benefit turtles

The author declares no competing interests.

References

Adkins et al. (2017). Center for Biological Diversity, Ohio River Foundation, Ohio Wetlands Association, Kent Environmental Council, Friends of the Ravines, & Dr. Lisa Regula Meyer. Petition to end collection of unlimited numbers of wild common snapping and softshell turtles. https://www.biologicaldiversity.org/campaigns/southern_and_midwestern_freshwater_turtles/pdfs/Freshwater_turtles-Ohio_petition_1-5-2017.pdf

AFWA CITES Technical Work Group. (2020). Case study: U.S. freshwater turtles and tortoises in the context of the Convention on International Trade in Endangered Species of Wild Fauna and Flora. https://www.fishwildlife.org/application/files/7815/9352/0162/Case_Study_U.S._Freshwater_Turtles_and_Tortoises_CITES_2020_FINAL.pdf

Akre, T.S., Parker, L.D., Ruther, E., Maldonado, J.E., Lemmon, L., & McInerey, N.R. (2019). Concurrent visual encounter sampling validates eDNA selectivity and sensitivity for the endangered wood turtle. *PLOS ONE*. https://doi.org/10.1371/journal.pone.0215586

Akre, T. (2020). Slow and steady can win: How Investing in turtle conservation projects can protect these vulnerable species [Webinar]. Wildlife Habitat Council. https://www.wildlifehc.org/knowledge-resource/slow-and-steady-can-win-how-investing-in-turtle-conservation-projects-can-protect-these-vulnerable-species/

Allison, D., Griffin, E., Miller, K.L., & Rider, S. (2010). U.S. sea turtles: A comprehensive overview of six troubled species. Oceana. https://oceana.org/wp-content/uploads/sites/18/U.S._Sea_Turtles_Report_FINAL1.pdf

Arkansas Game & Fish Commission. (2018). Commission approves new turtle harvest regulations https://www.agfc.com/en/news/2018/11/15/commission-approves-new-turtle-harvest-regulations/

Attum, M., Lee, Y.M., Roe, J.H., & Kingsbury B.A. (2008). Wetland complex and upland—wetland linkages: landscape effects on the distribution of rare and common wetland reptiles. *Journal of Zoology*, *275*(3), 245-251. https://doi.org/10.1111/j.1469-7998.2008.00435.x

Badje, A. (2021). Protect turtles on the move. Wisconsin Department of Natural Resources. https://dnr.wisconsin.gov/newsroom/release/44291

Benaka, L.R., D. Bullock, A.L. Hoover, & N.A. Olsen (editors). (2019). U.S. National Bycatch Report First Edition Update 3. U.S. Dept. of Commerce, NOAA. NOAA Technical Memorandum NMFS-F/SPO-190, 95 p. https://media.fisheries.noaa.gov/dam-migration/nbr_update_3.pdf

Bennett, E., & Loda, J. (2020). Robbing the wild. Center for Biological Diversity. https://www.biologicaldiversity.org/species/reptiles/pdfs/4_Robbing_the_Wild.pdf

Bennett Williams, A. (2018). Wildlife officers bust turtle trafficking ring, free hundreds of reptiles. *The News-Press*. https://www.news-press.com/story/tech/science/environment/2019/10/18/black-market-turtle-poaching-operation-busted-hundreds-turtles-freed/4021753002/

Bonasia, K. (2014). Graptemys oculifera: Ringed map turtle. Animal Diversity Web. https://animaldiversity.org/accounts/Graptemys_oculifera/

Bouchard, S.S., & Bjorndal, K.A. (2000). Sea turtles as biological transporters of nutrients and energy from marine to terrestrial ecosystems. *Ecology, 81*(8), 2305-2313. https://doi.org/10.1890/0012-9658(2000)081[2305:STABTO]2.0.CO;2

Brost, B., Witherington, B., Meylan, A., Leone, E., Ehrhart, L., & Bagley, D. (2015). Sea turtle hatchling production from Florida (USA) beaches, 2002-2012, with recommendations for analyzing hatching success. *Endangered Species Research, 27*, 53-68. https://www.int-res.com/articles/esr2015/27/n027p053.pdf

Buchanan, S.W., Buffum, B., Puggioni, G., & Karraker, N.E. (2018). Occupancy of freshwater turtles across a gradient of altered landscapes. *The Journal of Wildlife Management, 83*(2), 435-445. https://doi.org/10.1002/jwmg.21596

Butler, C.J. (2019). A review of the effects of climate change on chelonians. *Diversity, 11*(8). https://www.mdpi.com/1424-2818/11/8/138/htm

Carr, A. (1982). Surveys of sea turtle populations and habitats in the western Atlantic. NOAA technical memorandum NMFS-SEFC; 91. https://repository.library.noaa.gov/view/noaa/5469

Center for Biological Diversity. (2020). South Carolina governor signs bill to protect wild turtles from poaching, trade. https://biologicaldiversity.org/w/news/press-releases/south-carolina-governor-signs-bill-protect-wild-turtles-poaching-trade-2020-10-22/

Conf. 11.9 (Rev. CoP18). Conservation of and trade in tortoises and freshwater turtles. CITES. Retrieved from https://cites.org/eng/res/11/11-09R13C15.php

Cohen, D. (2018). Coastline county populations continue to grow. *U.S. Census Bureau*. https://www.census.gov/library/stories/2018/08/coastal-county-population-rises.html

Collaborative to Combat the Illegal Trade in Turtles (CCITT). (2018) https://parcplace.org/species/collaborative-to-combat-the-illegal-trade-in-turtles/

.Colteaux, B.C., & Johnson, D.M. (2017). Commercial harvest and export of snapping turtles (Chelydra serpentina) in the United States: trends and the efficacy of size limits at reducing harvest. *Journal for Nature Conservation*, *35,* 13-19. https://doi.org/10.1016/j.jnc.2016.11.003.

Congdon, J.D., Dunham, A.E., & Sels, R.C.V.L. (1994). Demographics of common snapping turtles (Chelydra serpentina): Implications for conservation and management of long-lived organisms. *American Zoologist, 34*(3), 397-408. https://doi.org/10.1093/icb/34.3.397

Convention on International Trade in Endangered Species of Wild Fauna and Flora. (1973). 993 U.N.T.S. 243. https://www.ecolex.org/details/treaty/convention-on-international-trade-in-endangered-species-of-wild-fauna-and-flora-tre-000483/

Convention on International Trade in Endangered Species of Wild Fauna and Flora. (1973). 993 U.N.T.S. 243. Checklist of CITES Species: Testudines. https://checklist.cites.org/#/en/search/country_ids%5B%5D=80&output_layout=alphabetical&level_of_listing=0&show_synonyms=1&show_author=1&show_english=1&show_spanish=1&show_french=1&scientific_name=Testudines&page=1&per_page=20

Cordero, G.A. (2016). The turtle's shell. *Current Biology, 27*(5), PR168-R169. https://doi.org/10.1016/j.cub.2016.12.040

Crawford, B.A., Moore, C.T., Norton, T.M., & Maerz, J.C. (2017). Mitigating road mortality of diamond-backed terrapins (Malaclemys terrapin) with hybrid barriers at crossing hot spots. *Herpetological Conservation and Biology, 12*, 202-211. http://www.herpconbio.org/Volume_12/Issue_1/Crawford_etal_2017.pdf

Cross, M. (2021). Conservation of Blanding's turtles in the Lake Erie watershed [Conference presentation. Ohio Wildlife Management Association. https://www.youtube.com/watch?v=CmnYuWA2fNU

Cuevas, E., Guzman-Hernandez, V., Uribe-Martinez, A., Raymundo-Sanchez, A., & Herrera-Pavon, R. (2018). Identification of potential sea turtle bycatch hotspots using a spatially explicit approach in the Yucatan Peninsula, Mexico. *Chelonian Conservation and Biology, 17*(1), 78-93. https://doi.org/10.2744/CCB-1263.1

Delaware Administrative Code Title 7 § 3900. Wildlife Seasons. https://regulations.delaware.gov/AdminCode/title7/3000/3900%20Wildlife/3904.shtml

Davy, C.M., Kidd, A.G., & Wilson, C.C. (2015). Development and validation of environmental DNA markers for detection of freshwater turtles. *PLOS ONE*. https://doi.org/10.1371/journal.pone.010965

Donlan, J.C., Wingfield, D.K., Crowder, L.B., & Wilcox, C. (2010). Using expert opinion surveys to rank threats to endangered species: A case study with sea turtles. *Conservation Biology*. http://seaturtle.org/library/DonlanCJ_2010_ConservBiol.pdf

Duncan, E.M., Broderick, A.C., Fuller, W.J., Galloway, T.S., Godfrey, M.H., Hamann, M., Limpus, C.J., Lindeque, P.K., Mayes, A.G., Omeyer, L.C.M., Santillo, D., Snape, R.T.E., & Godley, B.J. (2018). Microplastic ingestion ubiquitous in marine turtles. *Global Change Biology. 25*(2), 744-752. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.14519

Duncan, E.M., Botterell, Z.L.R., Broderick, A.C., Galloway, T.S., Lindeque, P.K., Nuno, A., & Godley, B.J. (2011). A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. *34,* 431–448. https://doi.org/10.3354/esr00865

Endangered Species Act. 16 U.S.C. § 1531 et seq. (1973). https://www.fws.gov/international/pdf/esa.pdf

Enge, K.M., Berish, J.E., Bolt, R., Dziergowski, A., & Mushinsky, H.R. (2006). Biological status report: Gopher tortoise. Florida Fish and Wildlife Commission. https://myfwc.com/media/19511/gt-biostatreport.pdf

Environmental Conservation Online System. U.S. Fish and Wildlife Service. https://ecos.fws.gov/ecp/

Fieseler, C. (2020). Chinese national held in global $2.2 million turtle smuggling scheme. *The Washington Post*. https://www.washingtonpost.com/climate-environment/2020/12/11/endangered-turtles-smuggling/

Florida Fish and Wildlife Conservation Commission. (n.d.). Gopher tortoise: Gopherus polyphemus. https://myfwc.com/wildlifehabitats/profiles/reptiles/gopher-tortoise/

Florida Fish and Wildlife Conservation Commission. (2021). Index Nesting Beach Survey Totals: 1989-2021. https://myfwc.com/research/wildlife/sea-turtles/nesting/beach-survey-totals/

Florida Fish and Wildlife Conservation Commission. (n.d.). Sea turtle lighting ordinances for Florida counties and municipalities. https://myfwc.com/media/3150/seaturtle-lightordmap.pdf

Food and Agriculture Organization of the United Nations (FAO). (2009). Fisheries and Aquaculture Department. Guidelines to reduce sea turtle mortality in fishing operations. https://www.fao.org/3/i0725e/i0725e.pdf

Fuentes, M.M.P.B., Gredzens, C., Bateman, B.L., Boettcher, R., Ceriana, S.A., Godfrey, M.H., Helmers, D., Ingram, D.K., Kamrowski, R.L., Pate, M., Pressey, R.L., & Radeloff, V.C. (2016). Conversation hotspots for marine turtle nesting in the United States based on coastal development. *Ecological Applications, 26*(8), 2708-2719. https://doi.org/10.1002/eap.1386

Fuentes, M.M.P.B., Allstadt, A.J., Ceriani, S.A., Godfrey, M.H., Gredzens, C., Helmers, D., Ingram, D., Pate, M., Radeloff, V.C., Shaver, D.J., Wildermann, N., Taylor, L., & Bateman, B.L. (2020). Potential adaptability of marine turtles to climate change may be hindered by coastal development in the USA. *Regional Environmental Change, 20*(104). https://doi.org/10.1007/s10113-020-01689-4

Georgetown County. Sea Turtle Outdoor Lighting Regulations/ Art. III. Beach Lighting, §§ 5.5-30--5.5-49. https://library.municode.com/sc/georgetown_county/codes/code_of_ordinances?nodeId=COOR_CH5.5BERE_ARTIIIBELI_S5.5-30PU

Gibbons, J.W., Scott, D.E., Ryan, T.J., Buhlmann, K.A., Tuberville, T.D., Metts, B.S., Greene, J.L., Mills, T., Leiden, Y., Poppy, S., & Winne, C.T. (2000). The Global Decline of Reptiles, Déjà Vu Amphibians: Reptile species are declining on a global scale. Six significant threats to reptile populations are habitat loss and degradation, introduced invasive species, environmental pollution, disease, unsustainable use, and global climate change, *BioScience*, *50*(8), 653-666. https://doi.org/10.1641/0006-3568(2000)050[0653:TGDORD]2.0.CO;2

Greico, M. (2018). The use of eDNA analysis to identify the habitat of spotted turtles [Poster presentation]. http://www.scienceandmathacademy.com/academics/srt4/student_work/2018/greico_mackense.pdf

Grey, E. (2015). Emydoidea blandingii: Blanding's turtle. Animal Diversity Web. https://animaldiversity.org/accounts/Emydoidea_blandingii/

Hamilton, C.M., Bateman, B.L., Gorzo, J.M., Reid, B., Thogmartin, W.E., Peery, M.Z., Heglund, P.J., Radeloff, V.C., & Pidgeon, A.M. (2018). Slow and steady wins the race? Future climate and land use change leaves the imperiled Blanding's turtle behind. *Biological Conservation, 222*, 75-85. https://doi.org/10.1016/j.biocon.2018.03.026

Harding, J., & Armitage, D. (2000). Glyptemys insculpta: (North American) wood turtle. Animal Diversity Web. https://animaldiversity.org/accounts/Glyptemys_insculpta/

Hawkes, L.A., Broderick, A.C., Godfrey, M.H., & Godley, B.J. (2009). Climate change and marine turtles. *Endangered Species Research, 7*, 137-154. https://www.int-res.com/articles/esr2009/7/n007p137.pdf

Hawkes, L.A., Broderick, A.C., Godfrey, M.H., & Godley, B.J. (2007). Investigating the potential impacts of climate change on a marine turtle population. *Global Change Biology, 13*(5), 923-932. https://doi.org/10.1111/j.1365-2486.2007.01320.x

Hays, G.C., & Hawkes, L.A. (2018). Satellite tracking sea turtles: Opportunities and challenges to address key questions. *Frontiers in Marine Science.* https://doi.org/10.3389/fmars.2018.00432

HerpMapper. About HerpMapper. https://www.herpmapper.org/about

Ihlow, F., Dambach, J., Engler, J.O., Flecks, M., Hartmann, T., Nekum, S., Rajaei, H., & Rodder, D. (2011). On the brink of extinction? How climate change may affect global chelonian species richness and distribution. *Global Change Biology, 18*(5), 1520-1530. https://doi.org/10.1111/j.1365-2486.2011.02623.x

Intergovernmental Panel on Climate Change (IPCC) WGII Sixth Assessment Report. Chapter 3: Oceans and Coastal Ecosystems and their Services. (2022). https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_FinalDraft_Chapter03.pdf

Intergovernmental Panel on Climate Change (IPCC) WGII Sixth Assessment Report. Chapter 4: Water. (2022). https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_FinalDraft_Chapter04.pdf

Jackson, J.C.B. (2001). What was natural in the coastal oceans? *Proceedings of the National Academy of Sciences, 98*(10). https://doi.org/10.1073/pnas.091092898

Janzen et al. (2018). Altered spring phenology of North American freshwater turtles and the impoprtance of representative populations. *Ecology and Evolution, 8*(11), 5815-5827. https://doi.org/10.1002/ece3.4120

Jeffers, V.F., & Godley, B.J. (2016). Satellite tracking in sea turtles: How do we find our way to the conservation dividends? *Biological Conservation*, *199*(2016), 172-184. https://doi.org/10.1016/j.biocon.2016.04.032

Jones, M.T., Roberts, H.P., & Willey, L.L. (2018). Conservation plan for the wood turtle in the northeastern United States. Report to the Massachusetts Division of Fisheries & Wildlife and the U.S. Fish & Wildlife Service. https://www.northeastturtles.org/uploads/3/0/4/3/30433006/woodturtleplan_2018_final_v2.2.pdf

Joyal, L.A., McCollough, M., & Hunter, M.L. Jr. (2002). Landscape ecology approaches to wetland species conservation: A case study of two turtle species in southern Maine. *Conservation Biology, 15*(6), 1755-1762. https://doi.org/10.1046/j.1523-1739.2001.98574.x

Kennedy, J. (2019). What eats sea turtles? *ThoughtCo*. https://www.thoughtco.com/sea-turtle-predators-2291405

Kessler, E.J., Ash, K.T., Barratt, S.N., Larson, E.R., & Davis, M.A. (2019). Radiotelemetry reveals effects of upstream biomass and UV exposure on environmental DNA occupancy and detection for a large freshwater turtle. *Environmental DNA.* https://doi.org/10.1002/edn3.42

Kimbrough, L. (2020). Turtles and tortoises in trouble: More than half of all species face extinction. *Mongabay News*. https://news.mongabay.com/2020/07/turtles-and-tortoises-in-trouble-more-than-half-of-all-species-face-extinction/

Lacey Act. (1900) 16 U.S.C. § 3371-3378. https://www.animallaw.info/statute/us-lacey-act-chapter-53-control-illegally-taken-fish-and-wildlife

Langen, T.A., Gunson, K.E., Scheiner, C.A., & Boulerice, J.T. (2012). *Biodiversity and Conservation, 21*, 3017-3034. https://doi.org/10.1007/s10531-012-0352-9

Lettrich, M.D., Dick, D.M., Fahy, C.C., Griffis, R.B., Haas, H.L., Jones, T.T>, Kelly, I.K., Klemm, D., Lauritsen, A.M., Sasso, C.R., Schroeder, B., Seminoff, J.A., & Upite, C.M. (2020). A method for assessing the vulnerability of sea turtles to a changing climate. NOAA Technical Memorandum NMFS-F/SPO-211. https://spo.nmfs.noaa.gov/sites/default/files/TMSPO211.pdf

Li, C., Wu, X., Rieppel, O., Wang, L., & Zhao, L. (2008). Ancestral turtle from the late Triassic of southwestern China. *Nature*, *476*(7221), 487-501. https://www.researchgate.net/publication/23501107_Ancestral_turtle_from_the_Late_Triassic_of_Southwestern_China

Louisiana Wildlife & Fisheries. Recreational reptile and amphibian collecting. https://www.wlf.louisiana.gov/page/recreational-reptile-and-amphibian-collecting

Lovich, J.E., Ennen, J.R., Agha, M., & Gibbons, J.W. (2018). Where have all the turtles gone, and why does it matter? *BioScience*, *68*(10), 771-781. https://doi.org/10.1093/biosci/biy095

Lyons, M.P., von Holle, B., Caffrey, M.A., & Weishampel, J.F. (2020). Quantifying the impacts of future sea level rise on nesting sea turtles in the southeastern United States. *Ecological Applications, 30*(5), e02100. https://doi.org/10.1002/eap.2100

Mali, I., Vandewege, M. W., Davis, S.K., & Forstner, M.R.J. (2014). Magnitude of the freshwater turtle exports from the US: Long term trends and early effects of newly implemented harvest management regimes. *PLOS ONE, 9*(1). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3903576/

Mannion, A. (2020). Bright lights and dark nights: The challenge facing sea turtles in the city. *Hakai Magazine*. https://www.hakaimagazine.com/article-short/bright-lights-and-dark-nights-the-challenge-facing-sea-turtles-in-the-city/

Mansfield, K.L., Wyneken, J., & Luo, J. (2021). First Atlantic satellite tracks of 'lost years' green turtles support the importance of the Sargasso Sea as a sea turtle nursery. *Proceedings of the Royal Society of Biological Sciences.* https://doi.org/10.1098/rspb.2021.0057

Marchand, M. et al. (2017). Coordinated monitoring strategy for Blanding's turtle in the northeastern United States: Project overview and implementation protocols. Northeast Blanding's Turtle Working Group. http://www.blandingsturtle.org/uploads/3/0/4/3/30433006/embl_crms_april17_2017.pdf

Maryland Administrative Code Title 08.02 § 06.01. https://casetext.com/regulation/maryland-administrative-code/title-08-department-of-natural-resources/subtitle-02-fisheries-service/chapter-080206-snapping-turtles/section-08020601-snapping-turtles#:~:text=(1)%20A%20person%20may%20not%20take%20or%20possess%20a%20snapping,the%20wild%20for%20noncommercial%20purposes.

Mazaris, A.D., Schofield, G, Gzakinou, C, Almpanidou, V, & Hays, G.C. (2017). Global sea turtle conservation successes. *Science Advances*, *3*(9). https://www.science.org/doi/10.1126/sciadv.1600730#:~:text=The%20reduced%20harvesting%20of%20turtles,10)%20and%20international%20conservation%20agreements

McClenachan, L., Jeremy, B., Jackson, C., & Newman, M.J.H. (2006). Conservation implications of historic sea turtle nesting beach loss. *Frontiers in Ecology and the Environment*, *4*(6), 290–296. http://www.jstor.org/stable/3868841

Mettler, E.K., Clyde-Brockway, C.E., Sinclair, E.M. et al. (2020). Determining critical inter-nesting, migratory, and foraging habitats for the conservation of East Atlantic green turtles (Chelonia mydas). *Marine Biology, 167,* 106. https://doi.org/10.1007/s00227-020-03724-8

Minnesota Department of Natural Resources. Recreational turtle license. https://www.dnr.state.mn.us/fishing/commercial/turtles.html#:~:text=An%20angling%20license%20is%20required,seller's%20licenses%20will%20be%20issued.

Montero, N., Ceriani, S.A., Graaham, K., & Fuentes, M.M.P.B. (2018). Influences of the local climate on loggerhead hatchling production in north Florida: Implications from climate change. *Frontiers in Marine Science*. https://doi.org/10.3389/fmars.2018.00262

Moran, K. L., & Bjorndal, K.A. (2005). Simulated green sea turtle grazing affects structure and productivity of seagrass pastures. *Marine Ecology Press Series, 305*, 235-247. https://www.int-res.com/articles/meps2005/305/m305p235.pdf

NOAA Fisheries. (2019). Fishing Gear: Turtle Excluder Devices. https://www.fisheries.noaa.gov/southeast/bycatch/fishing-gear-turtle-excluder-devices

NOAA Fisheries. (2020). Protected Species Observer Information for New England, the Mid-Atlantic and the Southeast.https://www.fisheries.noaa.gov/new-england-mid-atlantic/careers-and-opportunities/protected-species-observer-information-new-england-mid-atlantic-and-southeast

NOAA Fisheries. (2020). Sea Turtle Stranding and Salvage Network. https://www.fisheries.noaa.gov/national/marine-life-distress/sea-turtle-stranding-and-salvage-network

National Oceanic and Atmospheric Administration (NOAA). (2014). Marine Debris Program: Report on the entanglement of marine species in marine debris with an emphasis on species in the U.S. https://marinedebris.noaa.gov/sites/default/files/mdp_entanglement.pdf

National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management. (2018). Economics and demographics. https://coast.noaa.gov/states/fast-facts/economics-and-demographics.html

National Wildlife Federation. (n.d.). Green sea turtle: Chelonia mydas. https://www.nwf.org/Educational-Resources/Wildlife-Guide/Reptiles/Sea-Turtles/Green-Sea-Turtle

Nelms, S., Duncan, E. Broderick, A.C., Galloway, T.S., Godfrey, M., Hamann, M., Lindeque, P.K., & Godley, B.J. (2016). Plastic and marine turtles: A review and call for research. *ICES Journal of Marine Science, 73*(2), 165-181. https://www.researchgate.net/publication/282769498_Plastic_and_marine_turtles_A_review_and_call_for_research

Ohio Administrative Code. Rule 1501:31-25-04. Wild Animal Collecting | Reptiles and amphibians. Retrieved from https://codes.ohio.gov/ohio-administrative-code/rule-1501:31-25-04

Ohio Department of Natural Resources Division of Wildlife. (2021-2022). Ohio Fishing Regulations. Retrieved from https://ohiodnr.gov/static/documents/wildlife/laws-regs-licenses/Ohio+Fishing+Regulations+21-22+ENGLISH.pdf

Ohio Rev. Code §1531.02. State ownership of and title to wild animals – prohibited activities. Retrieved from https://codes.ohio.gov/ohio-revised-code/section-1531.02

Oklahoma Statutes. Title 29 § 4-103. https://oksenate.gov/sites/default/files/2019-12/os29.pdf

Oklahoma Department of Wildlife Conservation. 2021-2022 Fishing Regulations. https://www.wildlifedepartment.com/law/fishing_regs

Ontario Turtle Conservation Center. (n.d.). General comparison of reproductive potential of big-game species in Ontario. https://ontarioturtle.ca/turtles/turtles-roads/

Pajuelo, M., Bjorndal, K.A., Reich, K.J. et al. (2012). Distribution of foraging habitats of male loggerhead turtles (Caretta caretta) as revealed by stable isotopes and satellite telemetry. *Marine Biology, 159,* 1255–1267. https://doi.org/10.1007/s00227-012-1906-9

Parmesan, C., & Yohe, G. (2003). A globally coherent fingerprint of climate change impacts across natural system. *Nature, 421,* 37-42. https://www.nature.com/articles/nature01286

Patel, S.H., Winton, M.V., Hatch, J.M., Haas, H.L., Saba, V.S., Fay, G., & Smolowitz, R.J. (2021). Projected shifts in loggerhead sea turtle thermal habitat in the Northwest Atlantic Ocean due to climate change. *Scientific Reports, 11,* 8850. https://doi.org/10.1038/s41598-021-88290-9

Patrick, D.A., & Gibbs, J.P. (2010). Population structure and movements of freshwater turtles across a road-density gradient. *Landscape Ecology, 25*, 791-801. https://doi.org/10.1007/s10980-010-9459-0

Quesnelle, P.E., Fahrig, L., & Lindsay, K.E. (2013). Effects of habitat loss, habitat configuration and matrix composition on declining wetland species. *Biological Conservation, 160*, 200-208. https://doi.org/10.1016/j.biocon.2013.01.020

Quinn, D.P., Kaylor, S.M., Norton, T.M., & Buhlmann, K.A. (2015). Nesting mounds with protective boxes and an electric wire as tools to mitigate diamond-backed terrapin (Malaclemys terrapin) nest predation. *Herpetological Conservation and Biology, 10*(3), 969-977. http://www.herpconbio.org/Volume_10/Issue_3/Quinn_etal_2015.pdf

Rachmansah, A., Norris, D., & Gibbs, J.P. (2020). Population dynamics and biological feasibility of sustainable harvesting as a conservation strategy for tropical and temperate freshwater turtles. *PLoS ONE.* Https://doi.org/10.1371

Rapp Learn, J. R. (2015). Citizen scientists track declining box turtles. *The Wildlife Society*. https://wildlife.org/citizen-scientists-track-declining-box-turtle-populations/

Rhodin, A.G.J., Iverson, J.B., Bour, R., Fritz, U., Georges, A., Shaffer, H.B., & van Dijk, P.P. [Turtle Taxonomy Working Group]. (2021). *Turtles of the World: Annotated Checklist and Atlas of Taxonomy, Synonymy, Distribution, and Conservation Status (9th Ed.).* In: Rhodin et al. Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. *Chelonian Research Monographs 8*, 1–472. https://iucn-tftsg.org/wp-content/uploads/crm.8.checklist.atlas_.v9.2021.e3.pdf

Rhodin, A.G.J., Parham, J.F., Iverson, J.B., & van Dijk, P.P. [Turtle Taxonomy Working Group]. (2009). *Turtles of the World: Annotated Checklist and Atlas of Taxonomy, Synonymy, Distribution, and Conservation Status.* https://iucn-tftsg.org/wp-content/uploads/crm.8.checklist.atlas_.v9.2021.e3.pdf

Rhodin, A.G.J. & van Dijk, P.P. (2009). Setting the stage for understanding globalization of the Asian turtle trade: Global, Asian and American turtle diversity, richness, endemism and IUCN Red List Threat Levels [Presentation]. Conservation and Trade Management of Freshwater and Terrestrial Turtles in the United States. St. Louis, Missouri, 2010.

Riley, J.L, & Litzgus, J.D. (2014). Cues used by predators to detect freshwater turtle nests may persist late into incubation. *The Canadian Field-Naturalist, 128*(2). https://doi.org/10.22621/cfn.v128i2.1583.

Rust, R.W., & Roth, R.R. (1981). Seed production and seedling establishment in the mayapple, Podophyllum peltatum L. *The American Midland Naturalist, 105*(1), 51-60. https://www.jstor.org/stable/2425009?seq=1#metadata_info_tab_contents

Sea Turtle Conservancy (STC). (n.d.). Information about sea turtles: Threats from beach erosion. https://conserveturtles.org/information-sea-turtles-threats-beach-erosion/

Sea Turtle Conservancy (STC). (n.d.). Sea Turtle Migration-Tracking Education Program

Schwanz, L.E., Spencer, R.J., Bowden, R.M., & Janzen, F.J. (2010). Climate and predation dominate juvenile and adult recruitment in a turtle with temperature-dependent sex determination. *Ecology*. https://doi.org/10.1890/09-1149.1

Sifuentes-Romero, I., Wallace, B.P., & Wyneken, J. (2020). FAQs about sea turtles. *The State of the World Sea Turtles (SWOT) Report. 15*, 40-41. https://www.seaturtlestatus.org/articles/2020/2/27/faqs-about-sea-turtles-2020

Silliman, B.R., & Bertness, M.D. (2002). A trophic cascade regulates salt marsh primary production. *Proceedings of the National Academy of Sciences, 99*(16), 10500-10505. http://bertnesslab.com/docs/labpublications/Silliman%20and%20Bertness%202002.pdf

South Carolina Department of Natural Resources (SCDNR). (2008). South Carolina Ordinances Providing Protections to Sea Turtles Adopted by the State, Counties and Municipalities. https://www.dnr.sc.gov/seaturtle/volres/ordinances.pdf

South Carolina Department of Natural Resources (SCDNR). Administrative Rules and Regulations, Chapter 123-151.3. Exchange and transfer for certain native reptiles and amphibians. https://www.dnr.sc.gov/wildlife/herps/regs.html

South Dakota Administrative Code. § 41:07:10. Fishing Season and Methods | Turtles. Retrieved from https://sdlegislature.gov/Rules/Administrative/16920

Stanford, C. B., et al. (2020). Turtles and tortoises are in trouble. *Current Biology*, *30*(12), R721-R725. https://doi.org/10.1016/j.cub.2020.04.088

Stanford, C.B. et al. (2018). Turtles in trouble: The world's 25+ most endangered tortoises and freshwater turtles. *Turtle Conservation Coalition*. https://www.researchgate.net/publication/323534854_Turtles_in_Trouble_The_World's_25_Most_Endangered_Tortoises_and_Freshwater_Turtles_-_2018

Steen, D.A., & Gibbs, J.P. (2004). Effects of roads on the structure of freshwater turtle populations. *Conservation Biology, 18*(4), 1143-1148. https://doi.org/10.1111/j.1523-1739.2004.00240.x

Strickland, J., Colbert, P., & Janzen, F.J. (2010). Experimental analysis of effects of markers and habitat structure on predation of turtle nests. *Journal of Herpetology, 44*(3), 467-470. https://doi.org/10.1670/08-323.1

The Wildlife Society (TWS). (2014). Policy brief: Lacey Act. https://wildlife.org/wp-content/uploads/2014/12/TWS_PolicyBrief_Lacey-Act_Dec-2014.pdf

United States Department of Justice (DOJ), U.S. Attorney's Office, Southern District of Florida. (2021). Poachers of 93 protected sea turtle eggs sentenced to prison. https://www.justice.gov/usao-sdfl/pr/poachers-93-protected-sea-turtle-eggs-sentenced-prison

Valdivia, A., Wolf, S., & Suckling, K. (2019). Marine mammals and sea turtles listed under the U.S. Endangered Species Act are recovering. *PLOS ONE*. https://doi.org/10.1371/journal.pone.0210164

Van Lear, D.H., Carroll, W.D., Kapeluck, P.R., & Johnson, R. (2005). History and restoration of the longleaf pine-grassland ecosystem: Implications for species at risk. *Forest Ecology and Management, 211*, 150-165. https://americaslongleaf.org/media/odunyvsq/history-and-ecological-implications-of-restoring-llp-_forest-ecology-mngt_.pdf

Varo-Cruz, N., Hawkes, L.A., Cejudo, D., Lopez, P., Coyne, M.S., Godley, B.J., Lopez-Jurado, L.F. (2013). Satellite tracking derived insights into migration and foraging strategies of male loggerhead turtles in the eastern Atlantic. *Journal of Experimental Marine Biology and Ecology, 443*, 134-140. https://doi.org/10.1016/j.jembe.2013.02.046

Weber, N., Weber, S.B., Godley, B.J., Ellick, J., Witt, M., Broderick, A.C. (2013). Telemtry as a tool for improving estimates of marine turtle abundance. *Biological Conservation, 167*, 90-96. https://doi.org/10.1016/j.biocon.2013.07.030

Wilcox, C., Puckridge, M., Schuyler, Q.A., Townsend, K., & Hardesty, B.D. (2018). A quantitative analysis linking sea turtle mortality and plastic debris ingestion. *Scientific Reports, 8*, 12536. https://www.nature.com/articles/s41598-018-30038-z

Willey, L.L. et al. (2022). Distribution models combined with standardized surveys reveal widespread habitat loss in a threatened turtle species. *Biological Conservation, 266*, 109437. https://doi.org/10.1016/j.biocon.2021.109437

Willey, L. L. (2001). Identification guide to eastern box turtles [poster]. Northeast Partners for Amphibian and Reptile Conservation (Based on Dodd, C.K. Jr. 2001. *North American box turtles: a natural history.* University of Oklahoma Press, Norman, Oklahamoa, USA). http://www.northeastparc.org/products/pdfs/NEPARC_BoxTurtle_IDGuide.pdf

Wilson, E.G., Miller, K.L., Allison, D., & Magliocca, M. (2005). Why healthy oceans need sea turtles: The importance of sea turtles to marine ecosystems. *Oceana*. https://europe.oceana.org/sites/default/files/reports/Why_Healthy_Oceans_Need_Sea_Turtles_0.pdf

Witherington, B.E. (1992). Behavioral responses of nesting sea turtles to artificial lighting. *Herpetologica, 48*(1), 31-39. https://www.jstor.org/stable/3892916?seq=1#metadata_info_tab_contents

World Wildlife Fund for Nature. (2017). Sea turtle bycatch [Factsheet]. https://d2ouvy59p0dg6k.cloudfront.net/downloads/sea_turtle_bycatch_factsheet_032917_online.pdf

World Wildlife Fund for Nature. (n.d.). Sea Turtle Satellite Tracking Initiative.

Zimmer-Shaffer, S. A., Briggler, J.T., & Millspaugh, J.J. (2014). Modeling the effects of commercial harvest on population growth of river turtles. *Chelonian Conservation and Biology*, *13*(2), 227-236. https://doi.org/10.2744/CCB-1109.1