8. Threats and Predators

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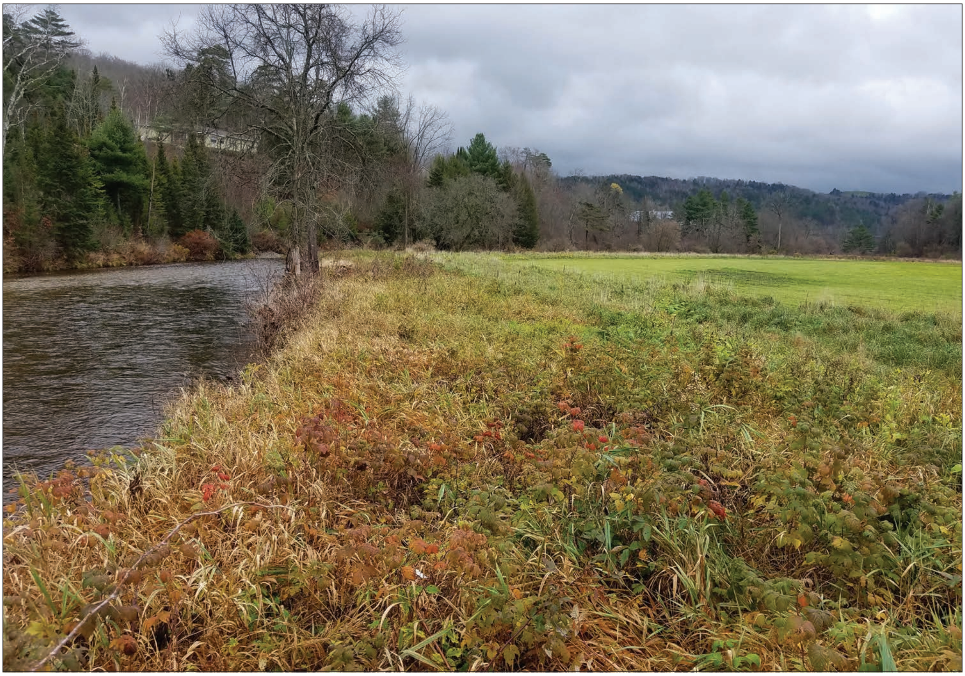
This female Wood Turtle in New England lost both front limbs to a mammalian predator. Mike Jones



8.1—Floodplain ecosystems preferred by Wood Turtles have historically provided rich soils for agriculture, clearly illustrated at this site in New England. Kiley Briggs

Introduction

For most of its evolutionary history, the lineage that led to modern *Glyptemys* thrived (and survived) in environments unimaginable to us today.[1] Today, we see a delicate animal undergoing ecological collapse across much of its recent range. However, the serious threats that imperil Wood Turtle populations today are wholly different from anything the species has experienced during most of its evolutionary history, which must have been heavily influenced by now-extinct megafauna species ranging from mastodons (*Mammut* spp.) to short-faced bears (*Arctodus* spp.) and the chaotic disruptions of continental glaciations. Consider that for almost all of the species' evolutionary history, since it diverged from Bog Turtle, for example, human beings were absent from the North American continent.[2] By contrast, Wood Turtles are now most influenced by urbanization, vast networks of roads, a massive agricultural footprint, countless reservoirs, a landscape mostly devoid of large predators, and a climate that's taken on a different sort of volatility. In fact, countless Wood Turtle populations have been extirpated—or at least severely compromised—by a combination of agriculture, urbanization, habitat loss and fragmentation, and their associated effects (Garber and Burger 1995; Daigle and Jutras 2005; COSEWIC 2007; Jones et al. 2015; Roberts et al. 2017; Willey et al. 2021).

1 Chapter 2 provides a more detailed examination of the Wood Turtle's evolutionary history.

2 Even if humans have been present in North American for 20,000 years, their overlap with the Wood Turtle, or its direct ancestor, accounts for less than 0.2% of the estimated time since *Glyptemys valentinensis* ranged the Niobrara River of Nebraska 11.5 million years ago.

In this chapter, we broadly outline and discuss the proximate causes of Wood Turtle population decline within the following categories: (1) habitat loss and fragmentation, including road mortality and agricultural mortality; (2) hydrological degradation, including dams and stream alterations; (3) collection and harvest; (4) disease; (5) climate-related environmental change, including floods and drought; and (6) predation. As already described in detail, the life history characteristics of Wood Turtles make reproductive adults particularly important to population persistence (Compton 1999). Many of today's most significant threats are those that disproportionately affect Wood Turtles.[3]

Habitat Loss & Fragmentation

Conversion and fragmentation of Wood Turtles' riparian habitats and adjoining upland areas comprise one of the greatest threats to the persistence of the species. While Wood Turtles primarily occupy floodplains, much of the upland habitat adjoining floodplains in the species' range has been converted to agriculture or development. In the Northeastern United States, over 50% of historically suitable stream habitat is estimated to have been impaired by fragmentation and/or land use changes (Jones et al. 2015; Willey et al. 2021). Many of the low and mid-elevation riverine ecosystems preferred by Wood Turtles have historically provided strategic real estate for the manufacture and transportation of goods, rich soils for agriculture, or, more recently, attractive water-frontage for residential development (8.1). The distinct factors associated with habitat loss, fragmentation, or modification are known or strongly suspected to negatively influence the distribution and abundance of Wood Turtles.

Road Mortality

Road mortality of adults, juveniles, and hatchlings is a major threat to the species throughout its range (Jones et al. 2015) (8.2), and is the likely the single most significant cause of population declines throughout urbanized areas of the Northeastern United States (Gibbs and Shriver 2002). Akre and Ernst (2006) considered road mortality one of the most severe threats facing Wood Turtles in Virginia, and attributed most of their observed mortalities to automobiles. In New Jersey, nearly 10% of validated Wood Turtle occurrence points are live and dead on-road observations (NatureServe 2021). Further, where roads serve as attractive areas for egg-laying, as on the George Washington National Forest of northwestern Virginia, the roadside nesting sites themselves may function as ecological traps (Akre 2010). Heavily trafficked forest management roads in otherwise remote landscapes can also be potentially hazardous features, where few other anthropogenic threats are present. Newly created forest roads can also open otherwise unfragmented habitat, allowing poachers and collectors to access sites more readily. In recent years, as abandoned railway lines have been

8.2—Road mortality of adult, juvenile, and hatchling Wood Turtles is a major threat to the species throughout its range. This adult male was killed along a state highway that closely parallels what must formerly have been an exceptional Wood Turtle river in central New England. Mike Jones

3 Chapter 7 describes the Wood Turtle's life history in detail.

8.3—Agricultural machinery—including mowers and tractors—cause significant mortality in rural Wood Turtle populations throughout their range, and is often the most important cause of adult Wood Turtle mortality. Most reported mortality has been observed in eastern Canada and New England. The adult female pictured here (*top*) was killed in a horse pasture during a radio-telemetry study in New England (*bottom*). Mike Jones

converted to recreational trails, reports have increased of Wood Turtles nesting along these trails (Franek and Ruziecki 2018), putting nesting females at risk of collection and nests at risk of stress or failure due to the incompatibility of the substrate, causing rock falls.

Breckenridge (1958) speculated that automobile traffic resulted in Wood Turtle mortality in Minnesota, but noted an absence of road mortality records, which he attributed to the species' relative rarity. This speculation is supported by data from Québec, where only 2 of 60 (3.3%) road-killed turtles in one study were Wood Turtles (Desroches and Picard 2005), and from central New England, where only 5 of 364 (1.4%) road-killed turtles were Wood Turtles (Jones, unpubl. data).

Agricultural Machinery

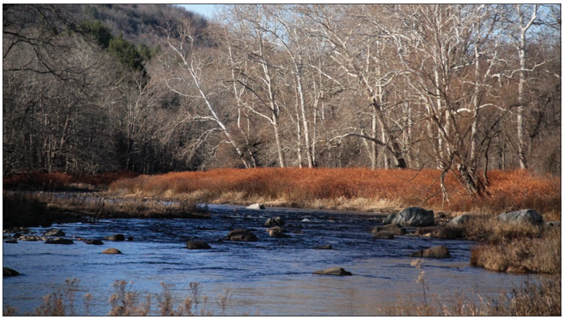
Wood Turtle mortality from crushing injury by agricultural machinery is a leading threat to many rural populations inhabiting both hay- and row-crop production areas (Saumure 2004; Daigle and Jutras 2005; Saumure et al. 2007; Castellano et al. 2008; Tingley et al. 2009; Jones 2009; Erb and Jones 2011) (8.3). Saumure and Bider (1998) first noted the severe effects of agricultural machinery on Wood Turtle survival. At their paired agricultural and forested sites in Québec, they noted that shell injuries were twice as common at the agricultural site. Jones (2009) reported that instream Wood Turtle density in Massachusetts was associated with low crop cover and higher forest cover at multiple landscape scales, suggesting that Wood Turtle densities are depressed in heavily farmed areas. Erb and Jones (2011) reported a substantial portion of the mortality associated with mowers is probably caused by tractor tires.

8.4—Active-season forestry operations can result in significant mortality or injury to Wood Turtles. Wood Turtles with serious shell fractures are regularly observed in remote areas of managed forestland. These older female Wood Turtles were found in relatively remote areas of New England forestland with severe—but healed—carapace fractures that were likely caused by forestry operations, forestry-associated vehicles, or mowing. Derek Yorks & Liz Willey

Forestry

The influence of forestry on Wood Turtles is complex, but can be either beneficial or detrimental to Wood Turtle viability depending on the scope, scale, configuration, seasonality, and methodology of the cutting operations, as well as the geographic position within the Wood Turtle's range. Historically, Wood Turtle populations probably centered around natural openings in the forest canopy, caused either by natural riverine disturbance processes or upland forest disturbances caused by fires, beaver, and severe wind blowdowns. Without such natural disturbances, Wood Turtles seek out their anthropogenic equivalents, such as areas cleared for timber harvest.

Some carefully planned riparian forestry practices (e.g., smaller harvest openings and shelterwood cuts) may create valuable basking and foraging microhabitat for Wood Turtles. However, active-season harvests can result in significant mortality or injury to turtles. Indeed, there is at least one report of a crushed adult Wood Turtle from a harvested location in northern Maine (deMaynadier, unpubl. data), and the authors of this chapter have observed Wood Turtles with serious shell fractures in remote areas of commercial forestland throughout New England



8.5—Japanese Knotweed (*Reynoutria* [=*Fallopia*] *japonica*)—appearing here as an orange understory shrub layer in a floodplain forest of American Sycamore (*Platanus occidentalis*) in Massachusetts (*left*), and along stream banks elsewhere in New England *(right)*—is probably the most ecologically problematic invasive plant species affecting Wood Turtle populations. Dense and established knotweed populations can impair the function of Wood Turtle nesting beaches. Mike Jones

(Jones, Yorks, and Willey, unpubl. data) (8.4). In addition, the elimination of a forested stream buffer due to timber harvesting can result in increased stream bank erosion, water quality and flow degradation, and reduced in-stream habitat heterogeneity from fallen trees and other riparian organic inputs (Akre and Ernst 2006; Tingley and Herman 2008). Structured or experimental research into the response of Wood Turtle populations to various forestry practices, including prescribed fire, is warranted.

Invasive Plants

Invasive vascular plant species are present throughout the larger floodplains of eastern North America. Their dispersal and colonization is facilitated by the dynamic nature of riparian systems, but in general, the negative effects of invasive plant species on Wood Turtles are poorly documented. The greatest risk posed by invasive vascular plants is likely reduced light availability for thermoregulation, reduced natural ground cover and forage availability, and loss of previously open, friable substrates for nesting. However, it is important to note that in some cases the process of controlling invasive species may involve greater risk for adult Wood Turtles than the plants themselves (e.g., Sparling et al. 2006), depending on the timing and mechanism for control.

The relative threat posed by invasive plant species probably varies geographically and according to the past land use and disturbance history of the site, as well as current management techniques. Invasive plant species influence the habitat quality of floodplain areas in different ways, depending on their density and growth form. Perhaps the most problematic invasive species for the Wood Turtle is Japanese Knotweed (*Reynoutria* [=*Fallopia*] *japonica*), which is known to overtake open, sandy nesting areas within the floodplain in Maine, New Hampshire, Vermont, Massachusetts, and Pennsylvania (Gipe and Jones, unpubl. data) (8.5). Multiflora Rose (*Rosa multiflora*) is also widespread and common in Wood Turtle habitats from Massachusetts (Jones 2009) to West Virginia (Niederberger 1993) and Virginia (Akre and Ernst 2006), and appears to present a threat to Wood Turtles only if aggressive efforts are made to control the species with heavy machinery during the active season. Other invasive plant species that may exert a negative influence on vegetation structure or sunlight availability in the river corridor include Autumn and/or Russian Olive (*Eleagnus* spp.), which has colonized Wood Turtle streams from New England to Virginia (Jones, unpubl. data; Sweeten 2008) and Mile-a-minute (*Persicaria perfoliata*), which has become problematic in Wood Turtle habitat from Pennsylvania to Virginia

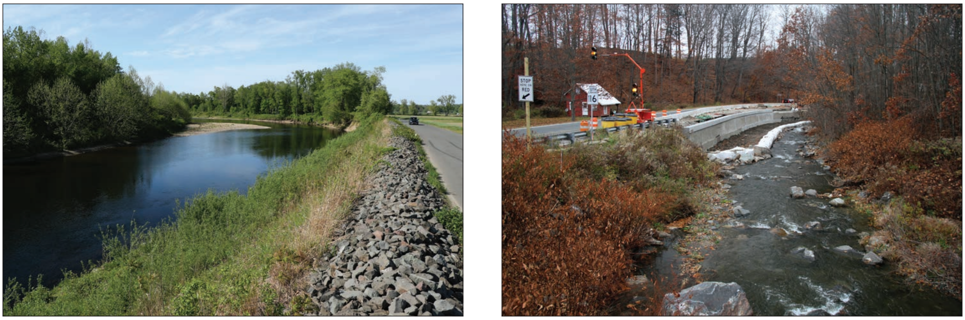
8.6—Coltsfoot (*Tussilago farfara*), shown here in its flowering and vegetative stages, is a Eurasian species now commonly found in Wood Turtle habitats range-wide. Although it is widespread, there is no evidence to suggest that Coltsfoot negatively influences the function of Wood Turtle habitat. Mike Jones

(Akre and Ernst 2006). At Great Swamp National Wildlife Refuge in New Jersey, Wood Turtle nesting areas are also negatively affected by Common Mugwort (*Artemisia vulgaris*) (Buhlmann and Osborn 2011). Wood Turtles actually feed upon some invasive plant species including Autumn Olive berries (Kleopfer, unpubl. data.) in Virginia and Japanese Knotweed, Reed Canary Grass (*Phalaris arundinacea*), and Bishop's Goutweed (*Aegopodium podagraria*) in Massachusetts (Jones and Sievert 2009b).

Other vascular plant species that may become problematic in riparian habitats include: Common Reed (*Phragmites australis*), Japanese Stiltgrass (*Microstegium vimineum*), several species of honeysuckle (*Lonicera* spp.), Garlic Mustard (*Alliaria petiolata*), Purple Loosestrife (*Lythrum salicaria*), Glossy Buckthorn (*Frangula alnus*), and Oriental Bittersweet (*Celastrus orbiculatus*) (PDEP 2004; Akre and Ernst 2006). Despite widespread concern, quantitative studies of the effects of invasive plant species on habitat quality for Wood Turtles are lacking. Many exotic species do not appear to negatively influence Wood Turtles, such as Coltsfoot (*Tussilago farfara*) or hawkweeds (*Hieracium* spp.), although there have not been any fine-scale studies to confirm this (8.6). Wood Turtles will occasionally bask in areas of dense Common Reed (Robillard et al. 2016).

Aquatic Pollution

The Wood Turtle is strongly associated with clear, clean streams (Harding 1991; Ernst and Lovich 2009). There have been few, if any, quantitative studies of the influence of aquatic pollution on Wood Turtle populations. Akre and Ernst (2006) indicated that poultry farms and logging in Rockingham County, Virginia, are degrading stream quality for Wood Turtles through point-source nutrient pollution and flow-rate degradation. Wood Turtles occur at least occasionally in streams affected by Acid Mine Drainage in western Pennsylvania, where they may be stained orange with ferric hydroxide (Williams 2009). Wood Turtles are largely absent from the mainstem of rivers that were used heavily during the textile boom of the 19th Century in Massachusetts (MassWildlife NHESP, unpubl. data; Jones, unpubl. data); however, these areas also tend to be heavily urbanized. More research into the effects of chemical and nutrient contamination on Wood Turtles is clearly warranted.



8.7—Bank stabilization or hardening is a common practice to minimize loss of residential or agricultural property caused by streambank erosion. Often, bank stabilization reduces the quality of bank and riparian habitat for Wood Turtles. Large, hardened structures can also influence downstream deposition patterns and can result in direct mortality of turtles during construction. Some rivers are heavily influenced by centuries of bank stabilization efforts, such as these sites in Massachusetts. Mike Jones

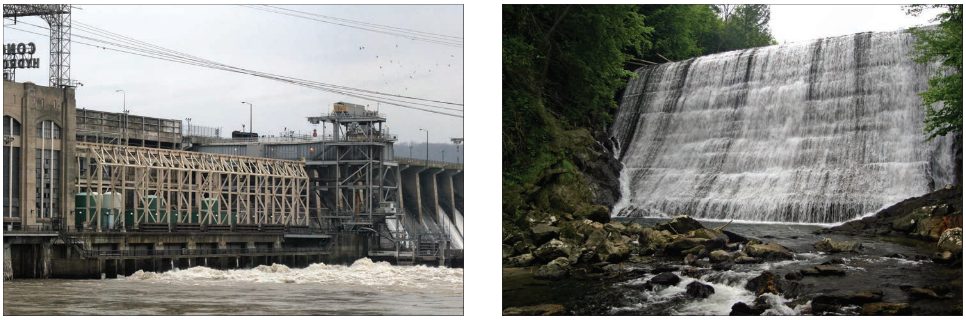
Hydrological Alterations

Stream Bank Stabilization

Stream bank alterations to control or contain streamflow have occurred in the eastern United States since European settlement. Artificial bank stabilization is common along rivers throughout the Wood Turtle's range wherever roads, buildings, agricultural fields, and energy infrastructure are at risk from flooding and massive bank failure. In many areas, a majority of available stream habitat has already been significantly altered or hardened. Bank stabilization ranges in form from the historical use of debris, broken cement, and riprap, to more recent applications of boulders, gabion, and bioengineering techniques (8.7).

Large-scale bank stabilization efforts can result in direct turtle mortality. Even small-scale bank stabilization has been documented to result in Wood Turtle mortality through crushing or entombment (Saumure 2004; Saumure et al. 2007). Bank stabilization projects can also degrade habitat for Wood Turtles in several ways depending on the materials used, extent of stabilization, and downstream hydrological changes. For example, riprap is also known to trap turtles of other species between the rocks as they try to navigate across the material (Kleopfer, unpubl. data). Banks hardened with large riprap (>20 cm) are probably of low habitat quality for Wood Turtles for several decades (Jones and Sievert 2011).

Large hardened structures can impair, impede, or influence natural depositional processes. Long sections of hardened bank can impair the natural dynamic movement of the river, slowing or obstructing the development of sand and gravel beaches on the inner bends of wide meanders. In this way, overall nesting-site quality can be degraded over the course of decades (Buech et al. 1997; Bowen and Gillingham 2004). In one large stream system totaling 17.1 km in length in western Massachusetts, Jones and Sievert (2011) reported that 7.5% of the streambanks had been converted to hardened structures of little ecological value to Wood Turtles, and an additional 3% of the river bank was exhibiting evidence of massive collapse, suggesting stream stabilization might be employed in the near future. The effects of bank stabilization on habitat quality for Wood Turtles merits further study, especially in the context of riparian and stream restoration programs.



8.8—Anthropogenic dams, including hydroelectric facilities, flood-control reservoirs, and drinking water reservoirs, have negatively influenced the distribution and abundance of Wood Turtles range-wide by converting suitable, free-flowing stream habitat to deep reservoirs and starving downstream beaches through altered flow regimes. The total effect is difficult to estimate, but is clearly enormous. The Conowingo Dam on the Susquehanna River in Harford County, Maryland, is pictured at left. One of thousands of defunct New England dams—in this case, a 19th-century power dam—is pictured at right. Mike Jones

Widespread stabilization projects occurred throughout New England and New York in the wake of Hurricane Irene (2011) and Tropical Storm Sandy (2012), many of which were implemented under emergency authorization (Murphy 2013). The effects of intensive stream stabilization on Wood Turtle habitat usage and suitability should be a priority for field evaluation.

Anthropogenic Dams

Anthropogenic dams, including hydroelectric facilities, have negatively influenced the distribution and abundance of Wood Turtles by converting suitable stream habitat to deep reservoirs, influencing downstream flow regimes, and other effects (8.8). The influence of dams on habitat suitability for Wood Turtles depends on other habitat resources available, the size of the dam, and the landscape configuration. According to the National Dam Inventory (2018), more than 10,000 dams remain in place on streams and rivers within the Wood Turtle's recent range in the United States alone, including 1,934 in New York, 1,514 in Pennsylvania, 1,327 in Massachusetts, and more than a thousand in Minnesota, Wisconsin, and Michigan. Distributed throughout this area, more than 1,600 large dams serve the primary purpose of: (1) storing drinking water; (2) generating hydroelectric power; and/or (3) providing flood protection.

Habitat loss associated with dam construction was among the highest threats to Wood Turtles identified by Castellano et al. (2009). Compton (1999) reported that a very large dam in western Maine posed several long-term threats to Wood Turtle persistence by: (1) starving the river of sediments that would otherwise build downstream gravel bars; (2) moderating high springtime flows that would scour nesting areas and deposit new gravel, resulting in overgrown nesting areas; and (3) generating midsummer high flows that flood low-lying nests.

In some instances, it is possible to confidently infer from historical reports that Wood Turtle populations were displaced by flooding associated with reservoir construction. For example, in the Catskill Mountains of southern New York, numerous drinking-water supply reservoirs such as the Blenheim-Gilboa and Schoharie Reservoirs have completely flooded valleys that probably contained optimal Wood Turtle habitat prior to flooding in the 1920s but, like most cases involving older impoundments, this can no longer be demonstrated empirically. A nearby dam, which forms the Pepacton Reservoir of the interior Catskills, impounded a major section of the East Branch of the Delaware River. Reeve Bailey collected Wood Turtles in the footprint of the future reservoir in July of 1935, prior to its flooding between 1954–1955. And, to the south of the Catskill massif, the Ashokan Reservoir flooded Esopus Creek (and other small creeks) between 1912–1914. In summary, Wood Turtles were distributed throughout the Catskill Mountains during the era of the reservoir construction, and individual turtles were probably displaced into less optimal habitats by the flooding.

Quabbin and Wachusett Reservoirs in Franklin, Worcester, and Hampshire counties, Massachusetts, flooded extensive areas of suitable Wood Turtle habitat associated with the major branches of the Swift River and Nashua River Valleys when construction began in the 1930s, evidenced by recent Wood Turtle records in tributaries to both reservoirs (MassWildlife NHESP, unpubl. data; Jones, unpubl. data).

Numerous reservoirs in the Highlands of northern New Jersey probably eliminated large, contiguous areas of occupied stream habitat for Wood Turtles. One specific example is the Monksville Reservoir, which flooded portions of the Wanaque River.

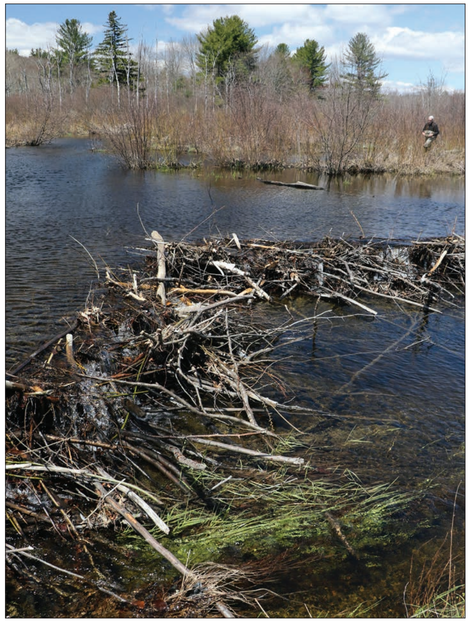
The Conowingo Dam is situated on the Susquehanna River in Cecil County, Maryland, where Wood Turtles were documented in the 1940s (Cooper 1949). Likely, some of the tributary streams affected by the Conowingo Dam were inundated.

Flood control facilities maintained by the U.S. Army Corps of Engineers are strategically placed to minimize property damage and loss of life within flood-prone communities. Army Corps flood storage projects include both reservoirs that are permanently flooded and many that are flooded only during major storm events, and both may negatively influence local Wood Turtle populations (Dickerson et al. 1999). Although it has not been studied, it is possible that large flood control projects can negatively influence Wood Turtle populations by creating dramatic shifts in water levels during the winter dormancy period, as well as by changing the downstream redistribution of sand, gravel, and woody material. Permanent flood-storage reservoirs located in close proximity to extant populations, it may be inferred, have likely resulted in long-term loss of free-flowing riverine habitat for local Wood Turtle populations, and in some cases may have caused interruptions in gene flow by serving as partial barriers to movement.

The local influence of smaller dams on riparian habitats is less clear. In Massachusetts, a small subpopulation of 10–15 adults was found to occur in free-flowing stream habitat immediately upstream of a late-19th century power dam, which had filled in with sediment and no longer formed a large reservoir (Jones and Sievert 2009). The dam appeared to create suitable riparian habitat for wood turtles upstream. However, individual turtles within this population were frequently displaced downstream and over the dam by repeated flood events. This appeared to result in reduced survival and reproductive output. The small reservoir remaining behind the dam also occasionally "captured" flood-displaced turtles (Jones and Sievert 2009). A similar situation occurred on a stream in New Hampshire (Jones, unpubl. data), suggesting that in some instances smaller dams can create suitable Wood Turtle habitat upstream after the resulting reservoir fills with sediment, which functionally reduces stream gradient and creates sandy bank structures. As dams are removed throughout the Wood Turtle's range, new opportunities will arise not only for stream and population restoration, but also to learn more about how such infrastructure may have affected Wood Turtle populations in the flooded areas.

Beavers

The relationship between habitat manipulations by American Beaver (*Castor canadensis*) and Wood Turtle population persistence is complex, highly variable at local scales, and not fully understood. Beavers are ecosystem engineers, keystone species that drive structural complexity (e.g., slower, deeper pools, basking and hibernation sites) within Wood Turtle streams. Beaver populations were once ubiquitous in eastern North America, as evidenced by the writings of early surveyors, naturalists, and fur trade records (Goldfarb 2018). Beaver populations periodically saturated the pre-Colonial American landscape, and they co-existed with Wood Turtles at least since the end of the Pleistocene ice ages. Beavers create mosaics of successional wetland communities by building and maintaining dams (8.9). Beaver populations in New England, however, had begun to decline due to human intervention by the mid-1600s and, by the 18th Century, beaver had been extirpated from Massachusetts (Goldfarb 2018). In Canada, the beaver fur trade peaked in 1875, when the Hudson's Bay Company traded over 270,000 pelts (Goldfarb 2018).



8.9—Beavers create mosaics of successional wetland communities by building and maintaining dams. Prior to their extirpation from many areas of eastern North America, beavers were undoubtedly a significant driver of vegetation dynamics within Wood Turtle river systems. A beaver-impounded Wood Turtle stream in New England is pictured. American Turtle Observatory

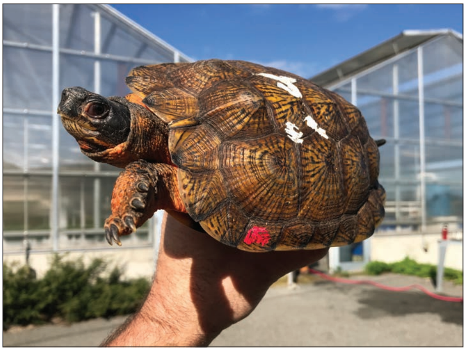
Today—especially within heavily fragmented or isolated Wood Turtle sites—beaver dam construction more often degrades site quality for Wood Turtles. Without adequate riparian connectivity to other areas of free-flowing lotic habitats, local Wood Turtle populations could be negatively affected. In the course of several radio-telemetry studies, we've noticed apparent avoidance of large beaver impoundments by Wood Turtles, in areas that were heavily used during periods when the beaver dams were defunct (Jones and Willey, unpubl. data).

As with many ecological processes the effects of beavers on Wood Turtle populations is likely a question of scale and may be similar to the patterns observed in fishes (Snodgrass and Meffe 1998); it is clear that in large landscape contexts, beavers can play an important role in the alteration and creation of various components of Wood Turtle habitat.

Collection and Harvest

Throughout their recorded history, Wood Turtles have been collected variously for food, scientific and museum collections, biological supply, and as pets. Today, Wood Turtles continue to be collected to satisfy a burgeoning international market in North American turtles (8.10). Many populations have been affected by collection, and most populations are vulnerable. Federal and state authorities lack the necessary resources and legal authority to put a meaningful end to the trade.

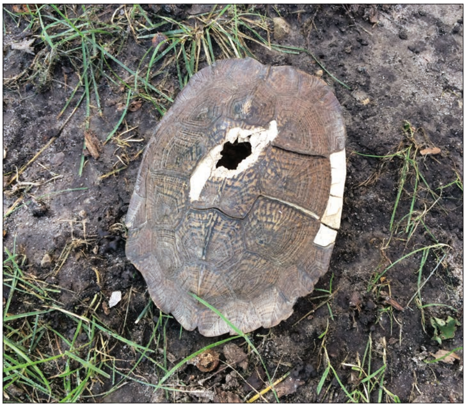
Wood Turtles were collected as a food item in the 19th and early 20th Centuries, contributing to population declines (Klemens 1993; Breisch 1997). By the mid-1900s, biological supply

8.10—Wood Turtles have been collected variously for food, scientific and museum collections, biological supply, and—more recently—as high-end pets. Today, Wood Turtles continue to be collected to satisfy a burgeoning, illegal international market in North American turtles, undermining efforts to protect and conserve otherwise functional populations. Until there is a more coordinated federal approach to regulate interstate and international trade in this species in the United States, many important wild Wood Turtle populations will remain at risk. The Wood Turtles pictured here were confiscated by wildlife agencies, and they represent populations throughout the eastern part of their range. John D. Kleopfer & Mike Jones

houses became a major detrimental cause of Wood Turtle population collapse (Vogt 1981), reflecting a trend that probably extends back several decades earlier (Jones et al. 2015).

In recent decades, illegal collection for domestic and foreign pet markets has become a major, unpredictable, regrettable threat (Compton 1999; NatureServe 2013). While the corrected, real price of Wood Turtles in the early 1960s was about $20.00, the price charged on online markets has climbed to more than $900 per turtle as of this writing.[4] The more than 45-fold increase likely reflects a decline in abundance (and availability).[5] Large-scale collection has been documented in



8.11—Wood Turtles are occasionally shot from their basking sites, as was this female in Iowa. Jeff Tamplin

4 In 2020, one dealer on Kingsnake.com lists adult Wood Turtles for $900 each, retail price (Saumure, unpubl. data).

5 The price of Wood Turtles has increased nonlinearly. A substantial increase occurred in the 1990s, when Wood Turtles were reported to sell for $125 in the early 1990s (RESTORE: The North Woods 1994), $131 in 1996 (Hoover 1998), $175 in 1997 (Compton 1999), and $250 in the late 1990s (McCollough 1997).

Maine,[6] Vermont,[7] New York,[8] New Jersey,[9] Pennsylvania,[10] Maryland,[11] Virginia, West Virginia,[12] Québec,[13] and Ontario.[14]

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6 The Maine Department of Inland Fisheries and Wildlife recorded at least two incidents of large-scale illegal collection of Wood Turtles from the wild. In 1994, approximately 44 Wood Turtles (mostly nesting females) were brought to the Portland waterfront to be sold (ME IFW, unpubl. data). In 1995, 54 Wood Turtles were confiscated from a dealer in Virginia who had obtained the animals in Maine (ME IFW, unpubl. data).

7 Vermont Fish and Wildlife undertook a sting operation in 2003 when it was reported that Wood Turtles were being advertised for sale on the internet; nine turtles were seized and released into their native stream (Parren 2013).

8 According to the New York Conservation Officers Association, Wood Turtles were one of the species most frequently collected and traded illegally as exposed by "Operation Shellshock," an undercover law enforcement action taken by the New York State Department of Environmental Conservation from 2006–2009. According to New York State Department of Environmental Conservation (Breisch, unpubl. data), a major confiscation of Wood Turtles occurred in Cattaraugus County in 2018.

9 In 2008, New Jersey environmental law enforcement, assisted by the Pennsylvania Fish and Boat Commission, raided the home of a commercial reptile breeder and found >20 Wood Turtles in his possession after he purchased four Wood Turtles from undercover agents (United States vs. Albert Roach, USDOJ/ECS 2011).

10 The Pennsylvania Fish and Boat Commission supported "Operation Herp Scam," which in 1998 detected a widespread network of trade in Wood Turtles (Sajna 1998) through which >290 Wood Turtles were taken from western and southwestern Pennsylvania (Blankenship 1999). Kaufmann (reviewing CITES listing in NatureServe 2013) reported that collectors from Canada illegally collected hundreds of Wood Turtles from a stream in Pennsylvania over the course of a few days.

11 Large-scale collection is suspected to have occurred in western Maryland in the early-2010s (Thompson, in Jones et al. 2015).

12 In 2008, the U.S. Fish and Wildlife Service contacted the Virginia Department of Game and Inland Fisheries to be on the lookout for a suspect of a surveillance operation in West Virginia. This effort led to the recovery of 108 illegally collected Wood Turtles. The Wood Turtles were released back at the reported point of capture in West Virginia. There have been other instances of commercial collection in West Virginia as far back as 1992. In 2013, a resident of Ontario, Canada was fined for possession and transportation of Wood Turtles from West Virginia. The investigation, conducted by the USFWS in conjunction with the West Virginia Division of Natural Resources Law Enforcement Section, determined that the Wood Turtles had been obtained from an undercover agent and transported to Ontario in violation of the Lacey Act and CITES (WV DNR, unpubl.data).

13 In order to promote the repatriation of confiscated Wood Turtles in Québec, all mark-recapture projects use the same numerical notching system using the posterior scutes per Saumure and Bider (1998). In addition, the anterior scutes are notched with a sequential population code, first instituted by the late Dr. Bider. Thus, a confiscated Wood Turtle notched as #27 with population code 3 can theoretically be verified based on sex and morphology, the poacher prosecuted, and the turtle returned to its home river.

14 An estimated 70% of a Wood Turtle population in Ontario was collected in a mass poaching event in the mid 1990s (White et al. 2016; Mullin 2019). Saumure (unpubl. data) recalls visiting a turtle hobbyist in Ontario in the mid-1980s who had over a hundred Wood Turtles collected in the United States.

Incidental collection of adult Wood Turtles contributed to the collapse of local populations in Connecticut (Garber and Burger 1995) and Virginia (Akre and Ernst 2006). Although not a widespread practice, Wood Turtles still appear at local turtle derbies (or races). In 2018 and 2019, Wood Turtles were unknowingly used for a turtle derby at the Frederick County Fair in Virginia (Kleopfer, unpubl. data). These turtles were wild-caught and housed with several Eastern Box Turtles (*Terrapene carolina*) in suboptimal conditions.

Clearly, incidences of Wood Turtle collection are widespread, and possibly increasing as the prices of animals continue to climb. As observed by Garber and Burger (1995) and modeled by Compton (1999), the loss of just a few individual adults from a population over time can lead to extirpation. It is fortunate that all extant range states currently prohibit commercial and/or personal collection of Wood Turtles. Better-integrated communication is needed between state wildlife agencies, law enforcement, and researchers. Wood Turtle populations would benefit from stronger deterrents such as higher penalties for collection of wild-caught Wood Turtles and a nexus for federal law enforcement to determine the legal status of captive Wood Turtles in any state. Most confiscations, particularly those that occur at the state level, lead to minor charges and penalties, much less than the market cost of the animals being trafficked. This does little to deter future collection.

There is no legal harvest of Wood Turtles anywhere in the species' range, though turtles are occasionally shot off their basking sites (Tamplin, unpubl. data) (8.11).

Pathogens

Disease has not yet been reported as a major problem influencing Wood Turtle population status (Smith and Anderson 1980; Upton et al. 1995), though emerging pathogens clearly warrant strong precautions by researchers. The presence of *Ranavirus* in captive and wild populations of Eastern Box Turtles, which are often sympatric with Wood Turtles from Massachusetts to West Virginia, is a growing concern (De Voe et al. 2004; Johnson et al. 2008; Allender et al. 2011; Kiester and Willey 2015). Although *Ranavirus* prevalence seems to be low in Eastern Box Turtles (Allender et al. 2011), several die-offs of unknown cause have occurred (Rossell et al. 2002), and incidents in New York, Pennsylvania, Georgia, and Florida may have been caused by *Ranavirus* (Johnson et al. 2008). In New Jersey, an individual headstarted Wood Turtle that was being monitored at its release site in the wild was found dead and tested positive for *Ranavirus* in 2015 (K. Conley, WCS, unpubl. data).

Several dead Wood Turtles and Eastern Box Turtles were found in Pennsylvania in 2014; samples subsequently taken of Wood Frog (*Lithobates sylvaticus*) tadpoles at the site tested positive for *Ranavirus* (Gipe, unpubl. data), though there was no diagnostic link to the turtle mortalities. A mass die-off of about a dozen Wood Turtles and 18 Bog Turtles (*Glyptemys muhlenbergii*) was reported in Monroe County, Pennsylvania in 2014, but the cause could not be determined (Gipe, unpubl. data), and an unidentified pathogen may be causing mortality in wild Bog Turtle populations in Massachusetts and New York (USFWS 2009).

Several instances of limb paralysis, thinning skin, and emaciation in Wood Turtles have been reported by the public. In these cases, the sick captive Wood Turtles were being housed with asymptomatic Box Turtles (Saumure, unpubl. data).

Parasites

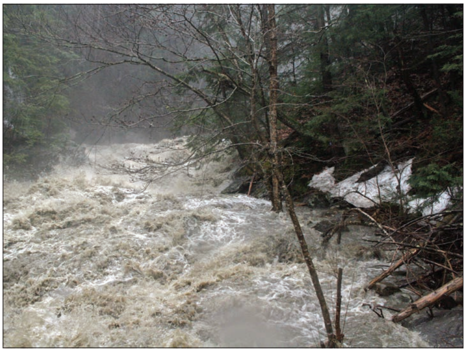
Wood Turtles are susceptible to ectoparasites, including biting flies (Grogan et al. 2009) and leeches (*Placobdella parasitica* or *P. ornata,* Koffler et al. 1978, Harding and Bloomer 1979; Hulse and Routman 1982; Routman 1982; Farrell and Graham 1991; Saumure and Bider 1996; Niederberger and Seidel 1999; Walde et al. 2003; Breisch 2006; Parren 2013). The severity of leech infestations varies seasonally (Koffler et al. 1978; Brewster and Brewster 1986; Farrell and Graham 1991; Walde et al. 2003), with most occurring in the spring and fall and fewer during summer months (8.12). Leeches may be detrimental to the turtles in concert with other disease or injury (Saumure and Bider 1996). Although there is no evidence that ectoparasites are a widespread threat to this species, *Placobdella* are known to transmit blood parasites in other sympatric turtle genera (Siddall and Desser 2001). Brown et al. (1994), however, did not find that *P. parasitica* had an effect on Common Snapping Turtle (*Chelydra serpentina*) reproductive output. Nevertheless, it is possible that Wood Turtles actively work to remove leeches and other parasites through behavioral processes such as basking or anting (Hughes et al. 2016). Though there is limited evidence for these behaviors to date, anti-parasite behavior is a potentially unexplored area of research.

8.12—Wood Turtles are often parasitized by harmless leeches in the genus *Placobdella*. A relatively old adult male Wood Turtle is pictured from central New England. Mike Jones

Climate-Related Threats

Flooding

The influence of severe flooding on Wood Turtle habitat quality, reproduction, survivorship, and dispersal is complex. Flooding, a naturally occurring phenomenon in most Wood Turtle streams, may improve or degrade habitat quality based on extent, magnitude, and seasonality. For example, floods may alter or rearrange channel geomorphology, damage floodplain vegetation, rearrange woody structure in the stream channel, or redistribute sand, gravel, and other sediments (Compton 1999), which in turn may either augment or decrease the available nesting habitat (8.13).



8.13—Severe flooding—especially floods in mountainous terrain resulting from spring rain on a heavy snowpack (*top*)—may alter or disrupt channel geomorphology, damage floodplain vegetation, and redistribute sand and gravel deposits used for nesting (*bottom*). Mike Jones

8.14—Severe flooding during the summer can directly result in nest failure if rising water inundates nesting areas for lengthy periods of time. Late-summer floods can result in complete nest failure by drowning hatchlings in the eggs (*left*) or cause young turtles to hatch and emerge prematurely from the nest (*right*). MIKE JONES

Flooding can also be a cause of nest failure, particularly mid-summer floods that over-wash sand bars, inundating low lying nests. While Wood Turtle eggs can sometimes survive flood events of several days (Vraniak and Geller 2017), late-season inundation can also prompt hatchlings to emerge prematurely from the nest (Jones 2009; Jones and Willey, unpubl. data) (8.14). Flooding is among the most important factors in the decline of Wood Turtle populations in Iowa, where Wood Turtles frequently nest on sandy stream banks and on riverbank sand bars below the high water line. Flooding has caused complete nest failure among known Iowa nests in 12 years out of approximately 15 years of monitoring (Tamplin, unpubl. data), and Spradling et al. (2010) reported 65% nest failure due to flooding from 2003–2006 in Butler County, Iowa.

Depending on the seasonal activity level of Wood Turtles at the time of the flood event, floods may directly entomb turtles through rapid deposition of sediment and debris, or displace them downstream (8.15). Severe floods may displace individual Wood Turtles from resting places within the stream channel, resulting in drowning or injury (Sweeten 2008; Jones and Sievert 2009). In a study of a western Massachusetts sream system, Jones and Sievert (2009) observed 17 displacements of 12 turtles ranging from 1.4 to 16.8 km during large floods, and they reported elevated mortality rates and depressed reproductive rates in flood-displaced animals. The smallest flood resulting in displacement observed in this study was approximately 14.5 times the average daily flow, or 24.4 m^3/s, although flows exceeding 248.0 m^3/s were observed. Disruptive floods in this system occurred at a rate of 1.7 per year during the study (2004–2008), higher than the

8.15—Floods during the winter inactivity season may directly displace or entomb dormant Wood Turtles. Displaced Wood Turtles may suffer limb or shell injuries, as pictured on this flood-displaced Massachusetts male (*left*). Wood Turtles may also be lethally entombed by rapid deposition of flood debris or by massive bank collapse, which trapped this Virginia female (*right*). TOM AKRE & MIKE JONES annual rate (0.5) of similar floods over the 38 years previous (1966–2004). The authors report that most turtles displaced more than 2 km did not return to their primary activity area within one year.

Sweeten (2008) observed likely flood displacement of three (of 36) adult Wood Turtles in November 2006 at a site in northwestern Virginia. Two males were displaced 13.6 and 19.8 km into the main stem of a larger river downstream, and one female was displaced 1 km. The author speculated that the displacement occurred because the turtles had returned to the river but had not yet "embedded" themselves for the winter in the rootmasses or undercut banks. Both males subsequently made large upstream movements; neither returned to their original capture location within one year.

8.16—Increasing anecdotal evidence suggests that prolonged droughts, which affect perennial streamflows, can subject Wood Turtles to elevated rates of depredation by mesopredators. This mature female was killed by an otter or mink during a prolonged drought in Concord, Middlesex County, Massachusetts—where the Wood Turtle has been functionally extirpated. Mike Jones

Flooding in Iowa has caused adult Wood Turtle mortality, as the turtles were buried under several feet of sand during extreme flooding events. Several other adult Wood Turtles were found dead shortly after major flooding receded in Iowa (Tamplin, unpubl. data). Lapin et al. (2019) further documented effects of flooding on mortality and survivorship in Iowa.

Recent observations of significant displacement or mortality during floods from Massachusetts, West Virginia, and Iowa—across the range of the Wood Turtle—may in part be caused by increasing precipitation severity, combined with increased impervious surface cover and bank stabilization within Wood Turtle watersheds. Indeed, flood severity is increasing as the result of more intense precipitation events, streambank stabilization projects, and the presence of increased impervious surface area in the watershed (Jones and Sievert 2009). Floods can also be exacerbated by the removal of beavers and their dams that create large wetlands that slow the downstream rate of floodwaters (Green and Westbrook 2009; Goldfarb 2018).

Latham (1971) reported five dead adult Wood Turtles washed ashore at four beaches on Long Island between 1919–1926, clustered in a small area directly across Long Island Sound from the mouth of the Connecticut River. Sightings occurred in May, June, July, and August, the inverse of the range of displacements observed by Jones and Sievert (2009), who reported most displacements in late fall, winter, and early spring in the upper portion of the Connecticut River. Latham reported that the sightings corresponded to "freshets," in which "trash, logs, broken trees" were washed from the rivers of Connecticut. Additionally, a single Wood Turtle was collected at Kingstown, Washington County, Rhode Island, on the shore of Narragansett Bay, circa 1980 (MCZ 166324), and a dead turtle was observed on a saltwater beach at Little Compton, Newport County, Rhode Island, in the 1990s (Yorks, unpubl. data). These last two locations are dozens of kilometers from the nearest confirmed location and may represent flood-displaced individuals from the Taunton River watershed in Massachusetts, or another coastal drainage.

In addition, floods can exacerbate the downstream colonization of aggressive vascular plant species such as Japanese Knotweed, mentioned above as one of the most problematic invasive species for Wood Turtles. This species can be particularly invasive in flood-prone ecosystems because of its propensity to root from plant fragments containing live nodes, and a deep root system (Colleran et al. 2020).

By contrast to the above-listed threats, floods may also positively influence genetic structure within watersheds. Flooding can provide a source of connectivity between lower-watershed populations and isolated subpopulations in the upper watershed.

Drought

As anthropogenic climate change causes more drastic climate events, not only are floods projected to increase, but drought events are also expected to become more frequent and severe. Such effects could alter habitat quality, change streams from permanent to ephemeral, reduce vegetation and foraging quality, or overheat nests. It could also reduce survival rates across all age classes, from nests and hatchlings to adults. In addition to direct mortality, drought could also alter movement patterns and behavior, which might have consequences for population connectivity; Remsberg (2006) found that turtles had smaller home ranges during two drought years compared to a more average year. Droughts can subject Wood Turtles to elevated rates of depredation, as Windmiller et al. (2017) reported in eastern Massachusetts in 2016 (8.16).

Flooding and drought have clearly been a part of the evolutionary context of the Wood Turtle, but anthropogenic climate change has exacerbated these natural phenomena. Floods and droughts are occurring with increased frequency and magnitude. Coupled with landscape change that has increased fragmentation and impervious surface and decreased habitat connectivity, continued increased severity of flooding and drought in future years will lead to increased pressure on individuals and populations of Wood Turtles. As a result, maintaining landscapes that are resilient to these changes is increasingly important to consider in habitat conservation and management plans. Well-designed landscape- and watershed-scale conservation strategies can buffer the species from these increasing threats and make continued population persistence more likely.

Mesopredators

Nest Predators

Depredation of Wood Turtle nests and hatchlings by mesopredators (mid-sized carnivores) is a complex and major threat in many regions (Harding and Bloomer 1979; Brooks et al. 1992; Klemens 2000; Walde et al. 2003; Akre and Ernst 2006; Buhlmann and Osborn 2011; Cherry et al. 2015; Cochrane et al. 2015; Vraniak et al 2017; Marchand 2020) (8.17). Nest depredation rates appear highly variable: in some areas, mammalian mesopredators such as Raccoons (*Procyon lotor*) have been subsidized by anthropogenic development (Klemens 2000). At some sites

8.17—Depredation of Wood Turtle nests and hatchlings by mesopredators such as Raccoons (*Procyon lotor*) are a significant factor limiting recruitment in many regions. Nest depredation often occurs within the first few nights following egg deposition in late Spring, but may occur in August or September as hatchlings begin to emerge from the nest. Pictured: Raccoon scat intermixed with depredated Wood Turtle eggs on a nesting beach in Maine. Mike Jones where adult survivorship is relatively high, recruitment may nevertheless be minimal due to nest depredation and hatchling predation. In some well-studied Wood Turtle populations, egg depredation reaches 100% at some sites in some years (Harding and Bloomer 1979; Brooks et al. 1992).

Buhlmann and Osborn (2011) noted that Raccoons and Red Fox (*Vulpes vulpes*) were significant nest predators in New Jersey. Nest predation by American Badgers (*Taxidea taxus*) was noted by Vraniak et al. (2017) in Wisconsin. Cochrane et al. (2015) reported Badger depredation of nests in Minnesota, and also observed Striped Skunks (*Mephitis mephitis*), and Raccoons eating eggs in a Minnesota nesting area. Other mammalian nest predators include Virginia Opossum (*Didelphis virginiana*) and Coyote (*Canis latrans*).

8.18—Adult Wood Turtles are able to survive mesopredator attacks under some conditions, as evidenced by frequent (but highly variable) rates of limb loss in populations throughout their range. This female Wood Turtle in Massachusetts has survived and nested for at least fifteen years with a missing hind foot—which, for a Wood Turtle, is an extremely minor injury. MIKE JONES

Cochrane et al. (2015) also reported Common Ravens (*Corvus corax*) and American Crows (*Corvus brachyrhynchos*) eating eggs in a Minnesota Wood Turtle nesting area.

Hatchling Predators

Predators of hatchling Wood Turtles probably include every carnivorous animal larger than a Green Frog (*Lithobates clamitans*). In New Hampshire, Tuttle and Carroll (2005) report apparent depredation of hatchlings by Eastern Chipmunks (*Tamias striatus*) and birds, and speculate that Great Blue Herons (*Ardea herodias*) also eat hatchling Wood Turtles. In Ontario, Paterson et al. (2012) reported extremely high post-emergent mortality of hatchling Wood Turtles; only 11% survived from emergence to their first winter dormancy period. The authors inferred that most hatchlings had been eaten by small mammals. The mortality rate sustained by Wood Turtle hatchlings was much lower than observed in a similar sample of Blanding's Turtle hatchings in Paterson's (2012) study. Of 68 hatchling Wood Turtles monitored by Dragon (2014) in northwestern Virginia, only 17 survived to overwinter (25%), and the majority (66.7%) of deaths were due to predation, representing 50% of all hatchlings tracked. Wicklow (unpubl. data in Jones et al. 2015) reported that four monitored Wood Turtle hatchlings were eaten by Eastern Chipmunks, one was eaten by a Northern Short-tailed Shrew (*Blarina brevicauda*), one was eaten by a Striped Skunk, and two were unaccounted for.

Predators of Adults

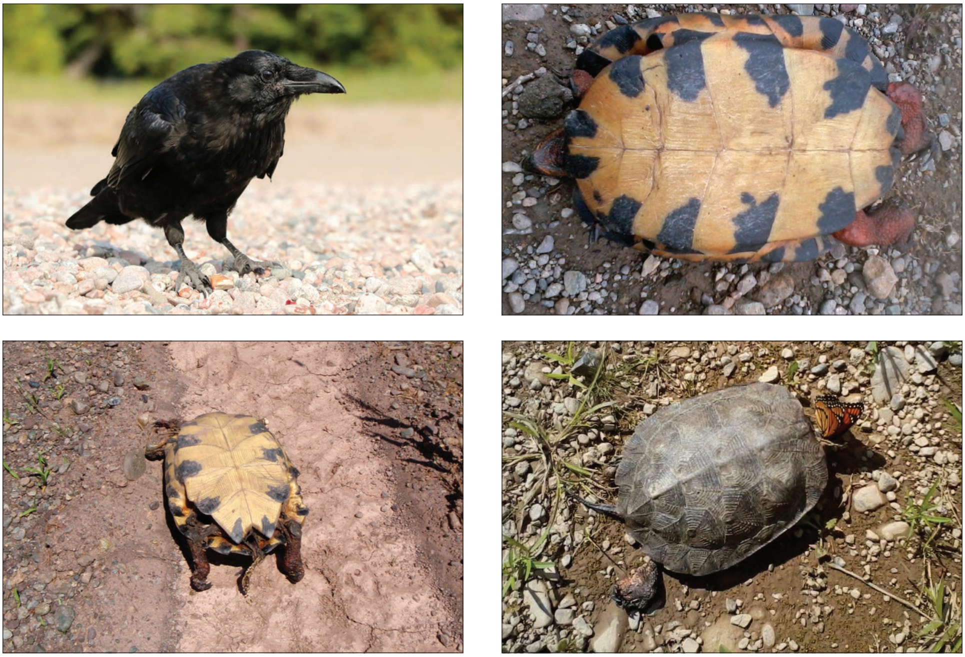
Mammalian and avian predators can mutilate adult Wood Turtles or kill them outright (Harding and Bloomer 1979; Farrell and Graham 1991; Saumure and Bider 1998; Walde et al. 2003; Akre and Ernst 2006; Jones 2009; Parren 2013). Adult Wood Turtles are preyed upon by Raccoons (Mullin et al. 2018; Lapin et al. 2019), Snapping Turtles (Tetzlaff and Ravesi 2015), and Ravens (McCullum 2016). Adult Wood Turtles are clearly able to survive predator attacks under some conditions, as evidenced by observed limb loss in populations throughout

8.19—Adult Wood Turtles are sometimes found missing all or part of two limbs (often their front limbs). Under some circumstances these turtles can evidently survive for several years in the wild. The turtles pictured here from New England. Mike Jones

their range: 9.7% in Michigan (Harding and Bloomer 1979); 16.8% in New Jersey (Farrell and Graham 1991), 32.3% and 15.2% at two sites in Québec (Saumure and Bider 1998), 48% at two populations in Massachusetts (Jones 2009), 43.5% of males and 5.5% of females in Vermont (Parren 2013) (8.18). Rarely, adults are found missing two limbs (8.19). Often though, the attack is lethal: three of 183 turtles radio-tracked by Jones (2009) were killed by mammalian predators, which represented 15.8% of the observed mortalities. Fourteen of the 36 mortalities observed on 141 transmitting Wood Turtles in the Midwestern U.S. were the result of predation, most thought to be Raccoon attacks (Lapin et al. 2019) (8.20).

8.20—Most mesopredator depredation is probably caused by Raccoons (*Procyon lotor*), but American Mink (*Mustela vison*) and North American River Otter (*Lontra canadensis*) are also likely mammalian predators of Wood Turtles. Sometimes, various threats can act synergistically— to lethal effect. Here, an adult female is pictured on a New England river beach after being attacked by a mink or otter. The predator removed all of the turtle's limbs and most of its face after it was displaced by a major flood in 2007. Mike Jones

Predation of adult Wood Turtles by corvids (primarily American Crows and Common Ravens) appears to vary by site and region, and in some locations is a major conservation concern and warrants consideration in



8.21—Predation of adult Wood Turtles by corvids appears to vary by site and region, but in some locations is a major conservation concern. Corvid depredation warrants consideration in management planning and additional targeted research. An adult Common Raven (*Corvus corax*) from Ontario is pictured (*top*), along with several adult Wood Turtles depredated by Ravens in New Brunswick (*bottom*). Deanna McCullum & Mike Jones

management planning. In New Brunswick, McCullum (2016) observed over 48 mortalities attributed to depredation by Ravens. More than 60 dead Wood Turtles were found at two nearby sites, attributed to the same cause (8.21). Marchand (2019) observed American Crows killing adult Painted Turtles (*Chrysemys picta*) in New Hampshire.

Many of the mesopredators causing mortality in Wood Turtles across age classes are "human commensals" (Klemens 2000); that is, their populations tend to be larger in anthropogenic landscapes. Although Wood Turtles co-evolved with these species and healthy turtle populations are likely able to withstand low levels of predation of all age classes, because today's landscape supports much greater numbers of mesopredators as a result of human subsidy and lack of apex predators in most parts of the Wood Turtle's range, predation rates are likely much higher than prior to European settlement.

Summary

Wood Turtle populations throughout their range are subject to increasing, interacting, and compounding threats that suppress population viability, causing the many observed population declines and extirpations. Where these threats are relatively minimal, it is important to implement a landscape-based conservation strategy that insulates turtle populations from excessive human influence and use. Where these threats are deeply entrenched and intractable, it is sometimes more appropriate to employ site-specific and stop-gap management efforts, which can buy time if well-designed.

Biology & Conservation *of the* Wood Turtle

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