Wood Turtle

Glyptemys insculpta (LeConte 1830)

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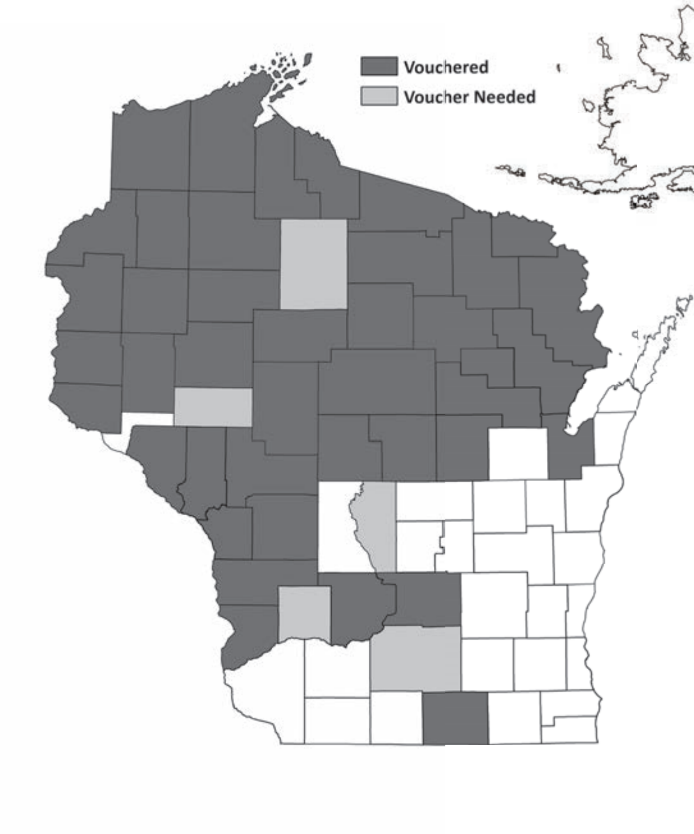

Adult Wood Turtle (Oneida County; photo by D. Brown).

AT A GLANCE

The Wood Turtle is arguably one of the most attractive and interesting freshwater turtles in North America. It is a medium-sized species with yellow or orange coloration on its throat and forelegs and pyramid-shaped rings on its shell. The species is primarily distributed throughout the northern half and the west-central and south-central portions of the state. This mild-mannered species spends the winter hibernating in rivers and streams but spends much of its time feeding and basking on land in late spring, summer, and early autumn. Nesting occurs from late May to early July, and hatchlings typically emerge from nests in September. The Wood Turtle is an omnivorous species that is known for its ability to capture earthworms by rapidly stomping on the ground, which creates vibrations that cause the worms to emerge. Unfortunately, Wood Turtles are negatively affected by a variety of human activities and habitat modifications, and population declines have occurred across the species' distribution. It is currently listed as a Threatened species and considered a Species of Greatest Conservation Need by the WDNR.

Above, top: Figure 331. Adult Wood Turtle displaying its yellow-orange throat and forelegs (La Crosse County; photo by J. Kapfer).

Above, bottom: Figure 332. Adult Wood Turtle displaying its pyramid-shaped interior scutes (Oneida County; photo by D. Brown).

SYSTEMATICS

Glyptemys insculpta (Wood Turtle) was historically included in the genus *Clemmys* (McDowell 1964) with three other species: *C. guttata* (Spotted Turtle), *C. marmorata* (now *Actinemys marmorata,* Western Pond Turtle), and *C. muhlenbergii* (Bog Turtle). Recent phylogenetic studies found this application of *Clemmys* to be paraphyletic, but with strong support for *C. insculpta* and *C. muhlenbergii* as sister species, thus requiring the placement of both species into a separate genus, *Glyptemys* (Bickham et al. 1996, Holman and Fritz 2001, Feldman and Parham 2002, Crother 2017). There are no recognized subspecies of *G. insculpta*.

DESCRIPTION

Adults: The base skin coloration is dark brown, with yellow or orange on the throat and forelegs (Figure 331). Carapace coloration is primarily various shades of brown, often with black or yellow specks or streaks. The carapace has a low middorsal keel, and the scutes contain raised concentric growth rings, resulting in pyramid-shaped interior scutes (Figure 332). The posterior margin of the carapace is serrated due to offset marginal scutes. The plastron has a yellow base with a large black blotch on each scute (Figure 333). Additional information regarding morphology can be found in Ernst and Lovich (2009). The Wood Turtle is a medium-sized species. Mean CL of individuals ten or more years old for a population in La Crosse and Trempealeau Counties was 20.9 cm (8.2 in, $n = 28$) for males and 18.7 cm

Figure 333. Comparison of adult male (*left*) and female (*right*) Wood Turtle plastrons (Oneida County; photo by D. Brown). The concavity in male plastrons is a useful sex identifier for Wood Turtles and many other turtle species. Biologically, it assists with mating by helping males to hold their plastron against the rounded carapace of females (Pritchard 2008).

Figure 334. Hatchling Wood Turtles (Washburn County; photo by A. Badje).

(7.4 in, $n=48$) for females (Ross et al. 1991). The current record MCL is 24.0 cm (9.4 in) for a male in Maine (Jones and Compton 2010).

Preadult stages: Eggs are elliptical in shape (ca. 3.2 × 2.3 cm [1.3 × 0.9 in]), white in color, and smooth (Vogt 1981). Hatchlings have a gray or black body and plastron and light brown or tan carapace (Harding and Bloomer 1979, Vogt 1981; Figure 334). Juveniles have strongly flared posterior marginal scutes, a morphological characteristic absent in adult males (Ernst and Lovich 2009). Lovich et al. (1990) noted that mean hatchling PL was 2.66 cm (1.05 in, $n=8$) in Pennsylvania.

Variation: Adults are sexually dimorphic, with males having a deeply concave plastron and higher and narrower carapace (Harding 1997, Ernst and Lovich 2009; Figure 333). In addition, the cloacal opening of males is located posterior to the back edge of the carapace, a useful characteristic for definitive sex determination. Males are typically 7%–10% larger than females (Lovich et al. 1990). There is geographic variation in adult male skin pigmentation, with males in the Great Lakes region typically having light yellow or light orange coloration on their throat, neck, and forelimbs, while males in eastern populations typically have darker orange or red coloration (Harding 1997, Ernst and Lovich 2009).

Diagnosis: The Wood Turtle is characterized by a carapace that is depressed or angular in cross section, has no keel, and has strong elevated concentric grooves on each scute. This species has a yellow plastron with a bridge, 12 scutes, and large black blotches on the lateral edge of each scute. The jaws are not beaked, and the toes are webbed. Adult Wood Turtles can be distinguished from all other turtle species in Wisconsin by their distinct sculptured carapace (Figure 332). However, biologists sometimes misidentify Wood Turtles for Blanding's Turtles and vice versa (Robert Hay, Turtles for Tomorrow, personal communication). Adult Blanding's Turtles (*Emydoidea blandingii*) have a similarly patterned plastron, but their plastron is hinged, and they have a smooth dome-shaped carapace. Juvenile and subadult Blanding's Turtles have a flatter carapace and somewhat distinct annual growth rings, which could cause them to be confused with Wood Turtles. However, they lack a middorsal keel.

Wood Turtle eggs are similar in shape and appearance to numerous other aquatic turtles. However, the size of their eggs probably most overlaps with those of Blanding's Turtles and Northern Map Turtles (see Preadult stages subsection). It is anecdotally possible to distinguish Wood Turtle eggs from Blanding's Turtle eggs because shells of the latter have a rougher texture during earlier incubation periods, so that gently rubbing them together produces a gritty sound (R. Hay, personal communication).

DISTRIBUTION AND HABITAT

Global distribution: The Wood Turtle is restricted to the northeastern and north-central US and southern Canada (Ernst and Lovich 2009). The species ranges from Nova Scotia to eastern Minnesota. On the East Coast, Wood Turtle populations occur as far south as Virginia. An isolated population currently exists in northern Iowa (Spradling et al. 2010). This species occurred as far south as Georgia and Alabama during the last glacial cycle and moved north with the receding glaciers beginning ca. 12,000 years ago (Holman 1976, Parmalee and Klippel 1981, Amato et al. 2008).

Distribution in Wisconsin: County records indicate that the Wood Turtle is primarily distributed throughout the northern half and the west-central and south-central portions of the state. Of the published county records, voucher specimens could not be found for Adams, Dane, Eau Claire, Price, and Richland (see the Appendix). According to WDNR (2016b) records, live individuals collected in Adams County in 1950 were deposited at the Henry Vilas Zoo in Madison, Wisconsin. However, the zoo has no records of these turtles (Jeff Stafford, Henry Vilas Zoo, personal communication). The only known recent observation from Eau Claire County occurred in 2006, but no specimen or photograph was collected (R. Hay, personal communication). Casper (1996) questioned the validity of the Dane County and Rock County records, attributing both to potentially "displaced" individuals. A purported Dane County specimen exists at the UW–Madison Zoology Museum (UWZM 19168). This is a jar of eggs that museum records indicate belong to a Wood Turtle. There is no date of collection, and the only information accompanying the specimen is vague locality data (i.e., "Madison" and "Dane County"). Aside from the ambiguity of the specimen's origin, eggs are difficult to use for species identification, and thus Dane County remains an unconfirmed location. The only known specimen from Rock County was supposedly collected along the Rock River "11 mi. N. of Illinois Line" in 1933 by C. R. Naeser (UIMNH 2287). Based on Curtis (1959), the land associated with the southern Rock River was historically savanna. Wood Turtles are currently associated with primarily forested habitat in Wisconsin, although they are also known to heavily use canopy gaps (see Habitat subsection) and possibly occupied more open areas in Wisconsin in the past (see Natural History Box: Is the Wood Turtle a Forest Species?). In addition, areas of lowland hardwood forest that are potentially more suitable for Wood Turtles currently exist along the nearby Sugar River in southwestern Rock County, and pockets of southern hardwood forest occurred historically in southwestern Rock County (Curtis 1959).

Localities of possible occurrence: There are several counties without confirmed records that represent obvious gaps in the documented range of this species. According to WDNR (2016b) records, unconfirmed sightings exist for Juneau and Outagamie Counties. Future surveys may confirm their presence in these counties. Based on its presence in surrounding counties, the species could also occur in Pepin County. A handful of anecdotal reports also exist from Grant and Iowa Counties (WDNR 2016b), which would represent extensions in the known state distribution for this species. Wood Turtles are occasionally encountered in southeastern Wisconsin, such as Milwaukee County (e.g., MPM VZP833), Kenosha County, and Racine County (MPM VZP216). Pope and Dickinson (1928) mentioned a secondhand report of Wood Turtles near Waukesha (Waukesha County) in the summer of 1925. These locations are far outside of the currently documented range for this species, and the sporadic observations have often been attributed to translocations. Yet the shore of Lake Michigan in eastern Wisconsin was once dominated by forest (Curtis 1959), and habitat could have historically existed for this species in Milwaukee, Kenosha, and Racine Counties. However, given the current level of anthropogenic disturbance in this region, it seems unlikely that these recent observations represent the occurrence of viable populations.

Habitat: Wood Turtles are associated with clear and tannin-stained rivers, perennial streams, and creeks with moderate to fast currents and hard bottoms

NATURAL HISTORY BOX: Is the Wood Turtle a Forest Species?

The terrestrial habitat surrounding rivers and streams that are currently inhabited by Wood Turtles is often primarily forested (see Habitat subsection), which could indicate that the preferred terrestrial habitat of Wood Turtles is forest. However, the scientific literature does not entirely support this assumption. Early reports often indicated that Wood Turtle habitat was nonforested. For example, Allen (1868) stated that in summer Wood Turtles were "generally found in dry fields remote from streams or ponds" in Massachusetts. More recent studies have also observed Wood Turtles occupying distinctly nonforested areas. For instance, Farrell and Graham (1991) noted that their study stream was "surrounded by open, well-cropped pasture, and contained the largest Wood Turtle population known to exist in New Jersey at the time." Several investigations have concluded that individuals select for canopy gaps within a forest matrix (e.g., Compton et al. 2002), have found that individuals preferred young forest to mature forest (Arvisais et al. 2004), and have even indicated that individuals preferred nonforest to forest (Kaufmann 1992a, Dubois et al. 2009).

If Wood Turtles can survive in and possibly even prefer nonforested habitat, it is strange that in Wisconsin the species is currently only found in primarily forested regions. One possibility is that Wood Turtles historically occupied a much broader distribution in the state but have been relegated to forests since European settlement. In particular, the conversion of savanna and prairie habitats to agriculture could have resulted in the extirpation of local Wood Turtle populations in the southern portion of the state (see Conservation section). Several other anthropogenic landscape changes, such as the installation of dams throughout the state, could also have influenced where we find the species today. Unfortunately, we can only speculate on the natural distribution of Wood Turtles in Wisconsin prior to European settlement. Regardless, our knowledge of the ecology of this species indicates that although the Wood Turtle is a forest species, it should not be considered 'strictly' a forest species.

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(composed primarily of sand and/or gravel), as well as adjacent forested riparian and upland habitat with openings in the streamside canopy and suitable nesting habitat (Compton et al. 2002, Bowen and Gillingham 2004; Figure 335). Vogt (1981) stated that in Wisconsin "they are restricted in habitat to forested areas along fast-moving streams." Within their habitat complex, Wood Turtles follow an annual chronological sequence of aquatic and terrestrial habitat use patterns dictated by seasonal air and water temperature changes and vegetation dynamics (Arvisais et al. 2004, Brown et al. 2016). Thus, suitable aquatic and terrestrial habitats are required for occupancy by Wood Turtles (Bowen and Gillingham 2004).

Wood Turtles are primarily aquatic in the spring and autumn but mostly terrestrial in the summer (Cochrane et al. 2019). However, individuals will return to water even in the summer to move, thermoregulate, and sometimes mate (Kaufmann 1992a, Compton et al. 2002, Dubois et al. 2009). In the transitional periods of spring and autumn, male and female Wood Turtles favor riparian shrub cover, such as Gray Alder (*Alnus incana*), and grassy openings near their overwintering streams (Quinn and Tate 1991, Ross et al. 1991, Compton et al. 2002, Arvisais et al. 2004). The likely reason for this close proximity to water is to assist with thermoregulation by alternating between terrestrial and aquatic habitats depending on the air temperature (Arvisais et al. 2004). During the warmer summer months, male Wood Turtles continue to use these low-elevation riparian areas, while females tend to venture into

Figure 335. Wood Turtle habitat in northwestern Wisconsin (Douglas County; photo by D. Brown).

Figure 336. A female Wood Turtle laying eggs in well-exposed sandy soil (La Crosse County; photo by J. Kapfer).

the uplands, using mixed forest stands in proximity to grassy or scrub-shrub openings (Compton et al. 2002, Arvisais et al. 2004, Tingley et al. 2010). Knudsen (1957e) noted that Wood Turtles use a wide variety of holes and depressions for shelter, such as rabbit holes, hollow logs, and sod overhangs along gullies, and recent population surveys in Wisconsin and Minnesota agree with this statement (Carly Lapin, WDNR, and Donald Brown, West Virginia University / USFS, personal observations).

Wood Turtles likely select for habitat edges or areas with a diverse availability of habitat types rather than large areas of only one habitat type because their habitat selection is driven by both foraging and thermoregulatory needs (Kaufmann 1992a, Compton et al. 2002, Arvisais et al. 2004). Tuttle and Carroll (2005) studied terrestrial habitat selection of 53 hatchling Wood Turtles in New Hampshire and found that hatchlings selected dense herbaceous and woody cover for shelter and concealment from predators. A habitat selection study of headstarted juveniles in Wisconsin revealed that individuals strictly used riparian habitat close to flowing water edges (Todd Thayer, UW–Green Bay, unpublished thesis). In that study, some individuals almost exclusively stayed in the water near the shoreline, while others spent much of their time on land within several meters of the water's edge and used deciduous forest, Gray Alder, and sedge-dominated riparian habitat. Given that these are broad generalizations from a number of studies, we emphasize that individual Wood Turtles display strong associations with a variety of habitats, possibly due to discovery of local food resources over the course of a long lifetime (Kaufmann 1992a, Arvisais et al. 2002, Compton et al. 2002).

Buech et al. (1997) determined that preferred nesting areas in Minnesota included well-exposed sandy substrates within 40 m (131 ft) of flowing waterbodies (ca. 50% of nests were within 10 m [32.8 ft]), with slopes <40° and heights 2–5 m (6.6–16.4 ft) above the water line (Figure 336). These preferences seem to be consistent across the species' distribution (Harding and Bloomer 1979, Farrell and Graham 1991, Hughes et al. 2009), but exceptions have been observed. For example, Wood Turtles have been found nesting >600 m (1,969 ft) from flowing water in Wisconsin (Greg Kessler, WDNR, and R. Hay, personal observations). In addition, nesting is common in gravel along railroad grades in Ashland, Iron, Marathon, Monroe, and Washburn Counties (Vogt 1981, C. Lapin and R. Hay, personal observations). Bougie et al. (2020) documented nests between 0.5 and 330 m (1.6 and 1,083 ft, $n = 120$) from rivers in Oneida and Washburn Counties. Pallas (1960) found an individual nesting in a suburban backyard in New Jersey. Females nesting in open sand patches, where digging is easier than in gravel and compacted soil, will often dig a body pit prior to laying eggs, allowing the female to place the eggs deeper in the soil (R. Hay, personal observation). This may be because the female recognizes that the eggs need to be buried deeper, as these sites may be warmer at the surface than what is preferred, and/or the female may know that these sites could dry out faster than other nesting substrates (R. Hay, personal communication).

Wood Turtles overwinter in flowing water that does not freeze completely (Ernst and Lovich 2009). Individuals have been documented using muskrat burrows and overhanging tree roots along streambanks and resting unprotected on the stream bottom during the winter months (Bishop and Schoonmacher 1921, Farrell and Graham 1991, Quinn and Tate 1991, Neiderberger and Seidel 1999). In contrast, Greaves and Litzgus (2007) studied overwintering behavior in Ontario and reported that individuals rested exposed on the riverbed at a mean distance from shore and depth of ca. 1 m (3.3 ft). Several studies have documented multiple Wood Turtles using the same hibernaculum, as well as overwintering site fidelity (Farrell and Graham 1991, Parren 2013).

REPRODUCTION AND DEVELOPMENT

Breeding can occur at any time during the active season but primarily occurs in spring and autumn (reviewed by Ernst and Lovich 2009). Mating typically occurs in shallow water but sometimes occurs on land, and copulation can last ≥12 hours (Ernst 1986b, Niederberger and Seidel 1999, Ernst and Lovich 2009). Males typically rest their plastron on the carapace of the female, but occasionally plastron-plastron copulation occurs (Tronzo 1993, Mitchell and Mueller 1996). Figueras and Burke (2017) discovered that female Wood Turtles can store sperm for more than two years. Females usually lay one clutch of eggs per year but occasionally lay two (Akre 2002). In addition, females sometimes do not nest in a given year (Ross et al. 1991, Akre 2002). Number of eggs laid per clutch varies widely, with the current record being 20 eggs from an individual in Quebec (Walde and Saumure 2008). Based on clutches in northern Wisconsin collected from 2011 to 2013, clutch size ranged from 3 to 17 ($\bar{x} = 11$, $n = 156$; Table 21). Of the 1,792 eggs observed in 2012 and 2013, 369 (20.6%) were infertile (Table 21).

Nesting in Wisconsin occurs from 20 May to 7 July, although nesting after 30 June is uncommon, and hatchlings emerge between August and October (Carroll and Ultsche 2007, Walde et al. 2007, R. Hay, personal communication). Walde et al. (2007) observed strong nest-site fidelity for a population in Quebec, with 95% of females nesting at the same site in consecutive years. To our knowledge, communal nesting has not been reported for the Wood Turtle. However, multiple females will use the same nesting area. Presumably, this is driven by the availability of preferred (or tolerated) nesting habitat rather than a behavioral or reproductive strategy.

Vogt (1981) stated that eight eggs is the most common clutch size in Wisconsin, but Harding and Bloomer (1979) found that the mean in Michigan was 10.36 eggs per clutch. R. Hay documented a mean clutch size of 10.95 ($n = 195$) in northern Wisconsin (Table 21). Unlike most turtle species in Wisconsin, the Wood Turtle does not have temperature-dependent sex determination (Bull et al. 1985, Ewert and Nelson 1991). Buech et al. (2004) and Walde et al. (2007) found that embryos in Minnesota and Quebec, respectively, must complete development before winter or the nest will be lost. This is supported by recent observations

Table 21. Wood Turtle clutch sizes and infertility rates of naturally laid and artificially incubated eggs in northern Wisconsin from 2011 to 2013 (eggs incubated at 26°C [78.8°F]). Infertility rates for individual clutches ranged from 0 to 100% over the two years of observation. Infertility rates were especially high for clutches with at least five eggs (R. Hay, unpublished data).

Year	Clutches	Total Eggs	Clutch Range	Mean Clutch Size	Infertile Eggs (%)
2011	41	392	4–17	9.57	N/A
2012	78	904	3–17	11.59	197 (21.79)
2013	76	888	5–17	11.68	172 (19.37)

from Oneida and Washburn Counties (C. Lapin, personal observation). In addition, 12 Wood Turtle nests from the 2014 nesting season were monitored in Douglas County (G. Kessler, unpublished data). Of the 12 nests, 2 hatched in September, and the remaining 10 were excavated the following spring after the potential post-winter emergence period, which revealed that individuals died in the eggs as partially developed embryos. Lovich et al. (2014) found no evidence of Wood Turtles overwintering in nests in Pennsylvania over a 21-year period. However, Parren and Rice (2004) found one hatchling in May that likely survived a warm winter in Vermont before hatching.

Wood Turtles are a long-lived species with indeterminate growth (Lovich et al. 1990). Growth rates for juveniles were ca. 1 cm (0.4 in) per year in Pennsylvania, with growth slowing dramatically when individuals neared sexual maturity (ca. 16 cm [6.3 in]; Lovich et al. 1990). Mean MCL for individuals in Jackson County differed by 3.4 cm (1.3 in) between the ages of three ($\bar{x} = 9.6$ cm [3.8 in], $n = 2$) and five ($\bar{x} = 13.0$ cm [5.1 in], $n = 2$) and by 2.4 cm (0.9 in) between the ages of six ($\bar{x} = 14.0$ cm [5.5 in], $n = 5$) and nine ($\bar{x} = 16.4$ cm [6.5 in], $n = 6$; Table 22). Based on these data, the estimated mean annual growth rate was 1.1 cm (0.4 in) per year, with a corresponding weight increase of 80.1 g (2.8 oz) per year, between the ages of three and nine (Table 22). Sexual maturity is a function of size (male MCL = 19.2–20.0 cm [7.6–7.9 in], female MCL = 15.8–18.5 cm [6.2–7.3 in]; Ernst and Lovich 2009). Both males and females typically reach sexual maturity between the ages of 14 and 18 (Farrell and Graham 1991, Brooks et al. 1992), but according to Harding (1997), individuals in northern populations can take as long as 20 years to mature. The smallest gravid female found during a study in La Crosse and Trempealeau Counties was 17.1 cm CL (6.7 in; Ross et al. 1991).

Plastron growth rings can be used to reliably age individuals up to at least 15 years old, but reliability decreases with age because the distance between rings decreases and plastron wear obscures growth-ring delineation (Harding and Bloomer 1979). Thus, long-term capture-recapture studies are the best way to assess longevity in the wild. The oldest known individuals were part of a study conducted in Minnesota, which recorded adult males that were at least 48 years old in 2013 and adult females that were at least 55 years old in 2014 (Brown et al. 2015). In addition, Jones (2009) estimated that wild individuals in Massachusetts and New Hampshire exceeded 80 years old, based on a shell-wear index.

ACTIVITY

Wood Turtles in Wisconsin typically emerge from hibernation in March (Vogt 1981). However, the annual active period in a given year is influenced by environmental temperature (Merritt 1980, Dubois et al. 2009, Berg 2014); thus, emergence from hibernation varies from year to year. Wood Turtles have even been observed attempting to mate under ice in northern Wisconsin (Kevin Brewster, independent researcher, personal communication to R. Hay). For a population in Pennsylvania, Ernst (1986b) found

Table 22. Observed mean and ranges of juvenile and sub-adult Wood Turtle MCL and weights in Jackson County from 1990 to 1995. Ages were estimated from plastron growth rings (R. Hay, unpublished data).

Age (*N*)	**MCL, cm (in)**	**Weight, g (oz)**
3 (2)	9.6, 9.2–9.9 (3.8, 3.6–3.9)	119, 100–138 (4.2, 3.5–4.9)
5 (2)	13.0, 12.7–13.3 (5.1, 5.0–5.2)	269, 258–280 (9.5, 9.1–9.9)
6 (5)	14.0, 13.2–14.7 (5.5, 5.2–5.8)	356, 292–407 (12.6, 10.3–14.4)
7 (6)	14.7, 13.3–16.8 (5.8, 5.2–6.6)	407, 318–585 (14.4, 11.2–20.6)
8 (6)	15.3, 14.1–17.5 (6.0, 5.6–6.9)	478, 375–618 (16.9, 13.2–21.8)
9 (6)	16.4, 14.7–17.7 (6.5, 5.8–7.0)	603, 455–705 (21.3, 16.0–24.9)

that individuals were active at air temperatures as low as 3°C (37°F) and water temperatures as low as 6°C (43°F), but feeding in water did not occur unless water temperatures were ca. 17°C (63°F). In addition, Dubois et al. (2009) determined that daily terrestrial habitat use patterns were influenced by temperature selection. A more comprehensive review of temperature selection can be found in Ernst and Lovich (2009).

Space use and activity patterns of Wood Turtles are strongly tied to flowing water throughout the year. Pentecost and Vogt (1976) stated that "in Wisconsin, individuals tend to be much more aquatic than are members of eastern US populations," but no study has attempted to test this hypothesis. This species is primarily diurnal (Vogt 1981), although nesting sometimes occurs at night (Ernst 2001b). Brown et al. (2016) studied activity patterns of a population in Minnesota and found that individuals generally remained within 0.1 km (0.06 mi) of flowing water but occasionally moved much farther, with one male observed 0.4 km (0.25 mi) from flowing water. Two juveniles were observed ≥0.5 km (0.3 mi) from flowing water in Douglas and Iron Counties, respectively (R. Hay, personal observation), and an adult male was observed ca. 0.85 km (0.53 mi) from flowing water in Douglas County (Andrew Badje, WDNR, unpublished data). In addition, a gravid road-killed female was observed ca. 0.6 km (0.37 mi) from flowing water in Douglas County (R. Hay, personal observation). Females sometimes travel long distances in search of suitable nesting sites. Behler and Castellano (2005) found a gravid female that moved 3.9 km (2.4 mi) through upland habitat in Delaware, and Ernst (2001b) documented nest-searching movements up to 1 km (0.6 mi) in Pennsylvania. Individuals in Oneida and Washburn Counties have been documented traveling up to 3.2 km (1.9 mi) and 4.1 km (2.5 mi) to nesting habitat, respectively (C. Lapin, personal observation).

Wood turtles often use rivers and streams as long-distance movement corridors, traveling 1 km (0.6 mi) or more (Parren 2013). An unusually long-distance movement event was documented for a radio-tracked female in Vilas County that moved ca. 16 km (10 mi) upstream to a nesting site (K. Brewster, personal communication to R. Hay). In addition, two years after initial capture, an adult female was recaptured 10.1 km (6.3 mi) downstream from its first location in Douglas County (A. Badje, unpublished data). Carroll and Ehrenfeld (1978) studied the homing ability of this species and found that displaced individuals had high return success up to 2 km (1.2 mi), with displacement direction having no influence on homing ability. In addition, Tinklepaugh (1932) performed maze experiments with a Wood Turtle and concluded that it was highly intelligent for a reptile, with a visual learning ability equivalent to that of a rat.

Several studies have investigated the social behaviors of Wood Turtles. The most thorough investigation was conducted on a population in Pennsylvania by Kaufmann (1992b). He classified 27 different social behaviors, with most female-female interactions classified as nonagonistic and most male-male interactions classified as agonistic. Kaufmann (1992b) found that males displayed dominance hierarchies that were associated with age and size of individuals, which he referred to as an "absolute dominance" social structure because agonistic encounters were not associated with territory defense. Male combative behavior is most prominent during the spring and autumn mating seasons, tends to occur more often in water than on land, and often happens during attempted mating events (Farrell and Graham 1991, Kaufmann 1992b). Female aggression has been observed in relation to competition for preferred nesting sites (Rutherford 2012).

Although Wood Turtles clearly have a social system, they are not territorial (Kaufmann 1992b, 1995). However, individuals occupy one or more activity centers that are adjacent to stretches of flowing water (Compton et al. 2002). Because Wood Turtles use rivers and streams as travel corridors, it is challenging to quantify their use of space. If an individual has two or more activity centers separated by hundreds or thousands of meters, traditional home range estimators such as minimum convex polygons (MCP) can dramatically overestimate space use. For example, Quinn and Tate (1991) estimated that activity areas ranged from ca. 1 to 115 ha (2.5 to 284.0 ac) in Ontario, and Remsberg et al. (2006) estimated that activity areas ranged from

0.2 to 390.0 ha (0.5 to 964.0 ac) in Michigan, based on MCP estimators. However, published estimates for Wisconsin indicate that activity areas are generally small. Ross et al. (1991) radio-tracked a total of three males and four females in the summers of 1975, 1985, and 1986 in La Crosse and Trempealeau Counties. Based on MCP estimates, activity areas ranged from 0.08 to 0.41 ha (0.20 to 1.01 ac) and 0.27 to 0.91 ha (0.67 to 2.25 ac) for males and females, respectively. Similarly, Harding and Bloomer (1979) reported activity area estimates of 0.91 ha (2.25 ac) and 0.48 ha (1.19 ac) for two females in Wisconsin (specific location and home range estimator were not reported). Ross et al. (1991) also reported that mean minimum daily movement was 41.9 m (137.5 ft) and 27.4 m (89.9 ft) for males and females, respectively. Woods (1945) observed an individual traveling at a rate of 0.3 km/hr (0.2 mi/hr) and hypothesized that this was close to the maximum terrestrial travel speed for Wood Turtles.

Brewster and Brewster (1991) studied movement patterns of headstarted juvenile Wood Turtles in Vilas County. They found that all individuals remained within 40 m (131 ft) of the river channel where they were released but moved up to ca. 50 m/day (164 ft/day) in the river for the first eight days after release, with minimal movement afterward. Castellano et al. (2008) studied hatchling movement patterns in an agricultural field in New Jersey and found that minimum daily movement was between 7 and 34 m (23 and 112 ft), and individuals spent several days to weeks in the field prior to entering the stream. Tuttle and Carroll (2005) studied hatchling movement patterns in New Hampshire and found that hatchlings took 1–24 days to reach an adjacent stream ($\bar{x} = 6.2$ days), and mean minimum distance traveled was 26.8 m (87.9 ft) per day.

Adult Wood Turtles in the western Great Lakes region begin reducing their terrestrial activity in September and October and enter hibernation in October or November (Vogt 1981, Brown et al. 2016). After emergence from nests in late summer and autumn, hatchlings travel to flowing water within a few weeks and presumably begin hibernation shortly thereafter (Tuttle and Carroll 2005, Castellano et al. 2008). Walde et al. (2008) found that hatchlings could survive short-term bouts of freezing temperatures on land in Vermont. During hibernation, Wood Turtles are thought to be intolerant of anoxic conditions (Graham and Forsberg 1991, Ultsch 2006) and thus overwinter in flowing waterbodies such as rivers, creeks, and streams (Vogt 1981). Greaves and Litzgus (2007) found that individuals made short-distance movements underwater during the winter hibernation period (i.e., 0.1–10.0 m [0.3–32.8 ft] between relocations, which occurred at intervals of 7–12 days).

PREY AND PREDATORS

Wood Turtles are omnivorous and opportunistic feeders that eat a wide variety of plants and animals (Vogt 1981, Walde et al. 2003). Their aquatic diet consists primarily of insects and mollusks (Surface 1908, Lagler 1943). Brewster (1985) studied Wood Turtle behavior in a terrestrial enclosure in Oneida County. He reported that individuals fed on planted raspberries (*Rubus* spp.) and strawberries (*Fragaria* spp., fruit and leaves), Common Dandelions (*Taraxacum officinale*), Common Plantains (*Plantago major*), grasses, earthworms, and a Mallard (*Anas platyrhynchos*) duckling that died in the enclosure. Cochran et al. (2014) collected 7 stomach samples and 11 fecal samples from wild Wood Turtles in Brown County and found that common dietary items included dewberries and blackberries (*Rubus* spp.), White Mulberries (*Morus alba*), mushrooms, and invertebrates. Crayfish claws were observed in the feces of several gravid females from Wisconsin (R. Hay, unpublished data). Jones and Sievert (2009b) studied Wood Turtle foraging behavior in Massachusetts and New Hampshire. They detected individuals feeding on Spotted Salamander (*Ambystoma maculatum*) egg masses and animal carcasses (fishes and birds), in addition to plants, fungi, and invertebrates. Furthermore, an individual was observed feeding on a White-tailed Deer (*Odocoileus virginianus*) carcass in Oneida County (Jim Klosiewski, WDNR, personal communication). Ernst (2001b) observed consumption of Green Frog (*Lithobates clamitans*) adults and tadpoles. Castellano and Behler (2003) found individuals eating Corn (*Zea mays*) in an agricultural

NATURAL HISTORY BOX: Worm Thumping

Wood Turtles consume a notably wide variety of plant and animal foods, but anyone who spends much time observing these turtles, as I have, will certainly witness their fondness for earthworms. They display a unique behavior for obtaining this slimy prey variously called worm 'stomping' or 'thumping.' One cool but sunny spring morning I watched an adult male Wood Turtle emerge from the water and move slowly over the damp ground near shore. He stopped and began to push down with a front foot several times in succession, with increasing tempo, lifting and dropping the front of his plastron with each push. He then moved forward about 5 cm (2 in) and duplicated the process with the alternate foot. After repeating the procedure several times, he suddenly lunged forward, seized a worm in his jaws, yanked it upward, and quickly swallowed it. He continued with this behavior for about 20 minutes, catching and consuming six worms before moving into tall grass to bask. It has been speculated that thumping the ground may cause vibrations similar to those made by tunneling moles, driving worms to the surface to escape. Worm thumping has been observed for Wood Turtles in most parts of their range, but apparently not all populations or individuals do it. Whether it is a mostly learned or inherited behavior is still unclear, but it does seem rather stereotyped; we do know that the alternating limb pushing behavior is used for other things unrelated to feeding. For example, Wood Turtles will sometimes thump the ground during or after aggressive encounters with rival turtles, and courting males often mount a female and then lift and drop onto the female's carapace several times in succession with the same increasing tempo used in worm thumping.

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field in New Jersey. The most unique Wood Turtle foraging behavior involves rapidly stomping their forelimbs on the ground, which creates vibrations that cause earthworms to emerge (see Natural History Box: Worm Thumping). Kaufmann (1986) noted that this foraging behavior can last for over four hours at a time, with a mean yield of 2.4 worms/hour in Pennsylvania.

Like all turtle species, Wood Turtles are most vulnerable to predation at the egg and hatchling life stages (Paterson et al. 2012). Based on a manipulative field experiment in the Upper Peninsula of Michigan, Rutherford et al. (2016) concluded that predators mostly used soil disturbance cues to locate artificial Wood Turtle nests. Females exhibit high fidelity to nesting sites, and after the discovery of these locations by mesopredators (e.g., Raccoons [*Procyon lotor*]), nests can be subjected to repeated annual plundering (Browne and Hecnar 1995). Predation rates can be very high (e.g., 15 of 17 nests were lost to predators in Ontario [Brooks et al. 1992], 34 of 50 unprotected nests were lost to predators in Oneida and Washburn Counties [Bougie et al. 2020]), which can result in long-term population declines (Daigle and Jutras 2005, Browne and Hecnar 2007). Throughout their range in Wisconsin, once Wood Turtle nesting is under way for two or more days, predation of nests often occurs within 24–48 hours (R. Hay, personal observations). A mail survey was conducted in northwestern Wisconsin in 2013 to obtain landowner feedback regarding individual and nesting Wood Turtle observations. Of the respondents, all of those who had observed Wood Turtle nesting commented that they had not seen a Wood Turtle nest last more than two days before being destroyed by predators (G. Kessler, personal communication to R. Hay). In Wisconsin and Minnesota, nest predation has also been observed late in the nesting season (including just prior to emergence), as well as on unhatched nests the following year (C. Lapin and Madaline Cochrane, University of Minnesota–Duluth, personal observations). It appears that some of the earliest laid nests and those laid very late in the nesting season have the best chance at surviving, especially if nesting begins during a rainy night (R. Hay, personal observations). Nest predation by American Badgers (*Taxidea taxus*), American Black Bears (*Ursus americanus*), Raccoons, Red Foxes (*Vulpes vulpes*), and Striped Skunks (*Mephitis mephitis*) has been observed in Wisconsin and/or Minnesota (Cochrane et al. 2015, Vraniak et al. 2017, C. Lapin and R. Hay, personal observation, Kurt Staab, landowner, personal communication to R. Hay). Parasitic amoeba (*Entamoeba* spp.) have been implicated in captive hatchling deaths (MacNeill et al. 2002), but to our knowledge this is undocumented in the wild. Michell and Michell (2015) radio-tracked ten headstarted Wood Turtles (six one-year-olds and four two-year-olds) for two years following their release in New York and reported that survivorship was 100%.

Adults are less vulnerable to predation, but it does occur. Loss of limbs to Snapping Turtles (*Chelydra serpentina*) and mesopredators, particularly Raccoons, is common (Harding 1985, reviewed by Ernst and Lovich 2009). In Jackson County, ca. 20% of adult Wood Turtles encountered were missing part or all of one appendage (R. Hay, personal observation). Lapin et al. (2019) determined that predation accounted for 75% of known-cause deaths ($n = 12$) of radio-tracked adult Wood Turtles in Wisconsin and Iowa. Carroll and Ultsch (2006) documented limb mutilation of hibernating adults by North American River Otters (*Lontra canadensis*) and suggested that additional individuals were likely killed. Parren (2013) documented predation of an adult male by a Fisher (*Pekania pennanti*). In addition, although leeches probably do not significantly affect survival, leech parasitism is common for Wood Turtles in Wisconsin and elsewhere (Hulse and Routman 1982, Brewster and Brewster 1986).

CONSERVATION

Status: Globally, the Wood Turtle is listed as Endangered by the IUCN. It is considered a Species of Greatest Conservation Need and listed as Threatened in Wisconsin by the WDNR.

Populations: In areas where Wood Turtles are present, documented densities are quite variable due to the species' uneven local distribution. For example, in New Jersey, Harding and Bloomer (1979) recorded an average density of 12.5/ha (5/ac), with local densities as high as 50/ha (20/ac). In Pennsylvania, the density of Wood Turtles for an entire study area (240 ha [593 ac]) was 0.7/ha (0.3/ac), but the density in areas where most Wood Turtles were found was 4.4/ha (1.8/ac; Ernst 2001b). Using replicated surveys and *N*-mixture models, Brown et al. (2017) estimated that population sizes ranged from 5 to 77 across eight sites in northeastern Minnesota (sites = 380–560 m [1,247–1,837 ft] stretches of river). Buech et al. (1997) hypothesized that this uneven distribution was correlated with geologic factors, such as the distribution of soils from glacial outwash plains. Wood Turtle density appears to decrease with increasing latitude (Walde et al. 2003, Bowen and Gillingham 2004). For example, Walde et al. (2003) estimated Wood Turtle density to be 0.4/ha (0.2/ac) in Quebec.

Reported sex ratios and adult-to-juvenile ratios vary widely among studies for the Wood Turtle. Ratner and Anderson (1978) surveyed a population in La Crosse and Trempealeau Counties. The sex ratio was 1M:1.9F when nest-site captures were included in the calculation ($n = 57$) and 1.6M:1F when nest-site captures were excluded in the calculation ($n = 26$). Ross et al. (1991) reported a sex ratio of 1M:0.6F in La Crosse and Trempealeau Counties (after removing nest-site captures; $n = 27$) and 1M:1.9F in Vilas County ($n = 24$). In Jackson County, the adult-to-juvenile ratio was 3.4A:1J during spring surveys ($n = 120$; R. Hay, unpublished data). Based on spring surveys from 1990 to 1995 in Jackson County, the sex ratio (including females found on nest sites) was 1M:1.1F ($n = 93$; R. Hay, personal observations). In Michigan, the sex ratio was 1M:1.2F ($n = 191$; Harding and Bloomer 1979). In Iowa, Berg (2014) found a sex ratio of 1M:1F for a suburban population ($n = 32$) and 1M:1.5F for a rural population ($n = 60$). In addition, the adult-to-juvenile ratio was 11.7A:1J and 61A:1J, respectively. In Quebec, Daigle (1997b) found that the sex ratio was 1M:1.2F and that the adult-to-juvenile ratio was 4.8A:1J ($n = 52$). Walde et al. (2003) found that in Quebec, the sex ratio was 1M:1.6F when nest-site captures were included in the calculation ($n = 138$)

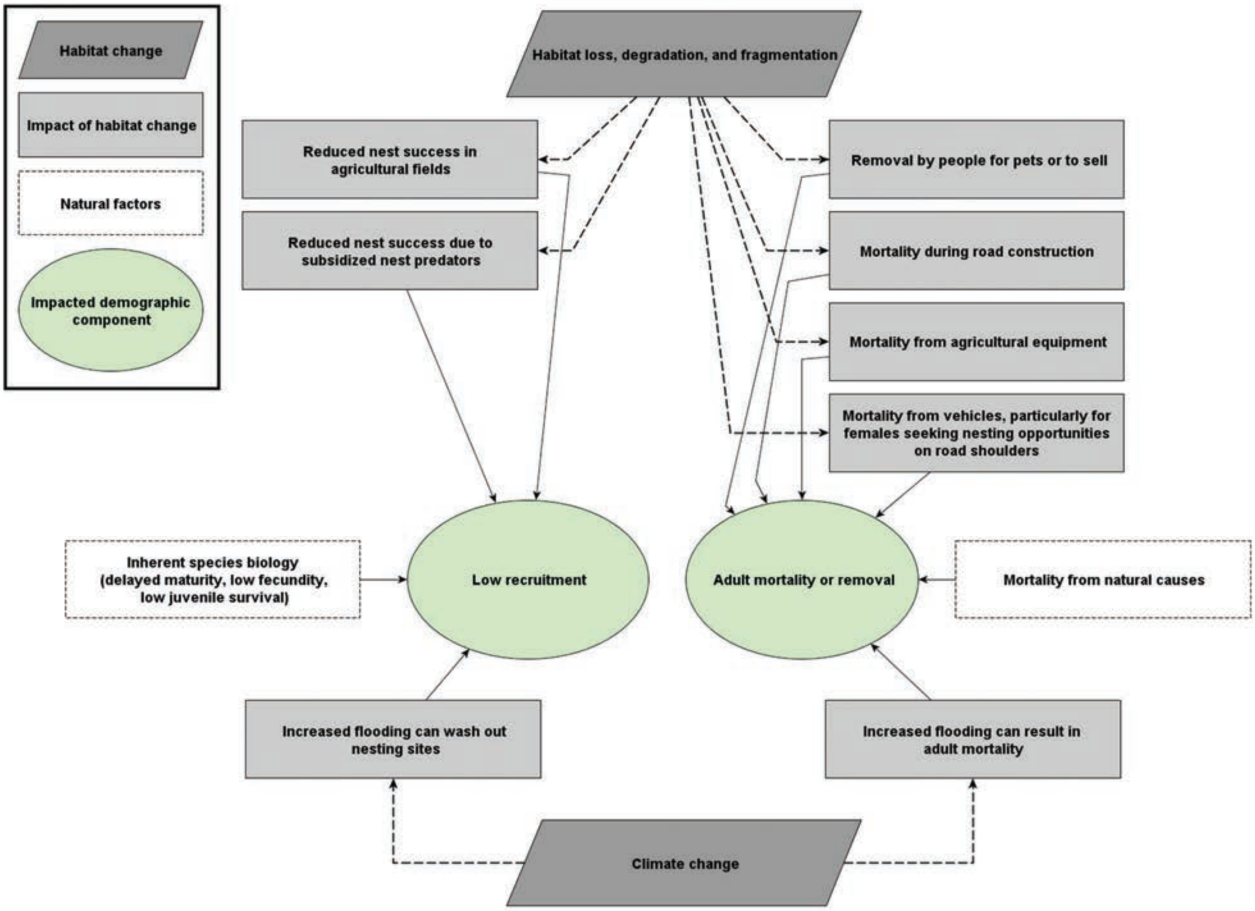

Figure 337. Major threats to Wood Turtle populations across the species' distribution and demographic components directly impacted by the threats. See Conservation section for further discussion and supporting references.

and 1M:1F when nest-site captures were excluded in the calculation ($n = 109$). Furthermore, Walde et al. (2003) documented an adult-to-juvenile ratio of 4A:1J when the population was surveyed in the spring and 2A:1J when the population was surveyed in the autumn ($n = 50$ juvenile captures). In Pennsylvania, the sex ratio was 1.4M:1F, and the adult-to-juvenile ratio was 3.2A:1J ($n = 88$; Ernst 2001b). In West Virginia, the sex ratio was 1.1M:1F, and the adult-to-juvenile ratio was 1.2A:1J ($n = 187$; Niederberger and Seidel 1999). In New Jersey, the sex ratio was 1M:1.6F, and the adult-to-juvenile ratio was 1.2A:1J ($n = 316$; Farrell and Graham 1991).

Threats: Wood Turtle populations are at risk of experiencing declines due to any adult mortality beyond natural levels due to their delayed maturity, low fecundity (small clutch sizes and typically only one clutch per year), and high juvenile mortality rates (see Reproduction and Development section; Figure 337). When these factors are combined with even a slight increase in adult mortality or removal, rapid declines and subsequent extirpations of local populations are expected (Burger and Garber 1995, Gibbs and Shriver 2002). For example, Garber and Burger (1995) observed the extirpation of two Wood Turtle populations over the course of just ten years after a wildlife area, previously closed to the public, was opened for recreation. Garber and Burger (1995) speculated that the cause of the declines was likely due to one or more of the following factors: "(1) removal, (2) road kills, (3) handling by recreationists,

(4) increased predation as a function of food waste and increased number of predators, and (5) disturbance by dogs."

An overall decline of Wood Turtle populations across their distribution has not been documented, but a compilation of available evidence (i.e., site and region-specific scientific literature, expert opinion, and results from temporally repeated site visits) suggests that the species has undergone drastic distribution-wide declines by as much as 50% or more in the last 100 years (Burger and Garber 1995, Bowen and Gillingham 2004, van Dijk and Harding 2011). In addition, average adult survival rates in Wisconsin, Minnesota, and Iowa may be lower than 0.9 (Lapin et al. 2019), which is likely lower than what is required for long-term persistence of populations (Compton 1999). Due to widespread long-term land and water use changes, many of the documented population declines are likely irreversible (van Dijk and Harding 2011). As is the case for most declining species, there are multiple factors contributing to the decline of Wood Turtles across their distribution (Figure 337). Habitat loss, degradation, and fragmentation (of both terrestrial and aquatic habitats) are currently the largest known threats to Wood Turtles (Burger and Garber 1995, Buech 1995, Buech et al. 1997, Ernst 2001a, Bowen and Gillingham 2004), and these issues are discussed in broad context in the Introduction to Conservation and Management of Wisconsin's Amphibians and Reptiles chapter. Below, we expound on two additional major threats for Wood Turtles: mortality from vehicular and agricultural equipment and climate change.

Vehicle traffic, road construction, and agricultural equipment are major threats to Wood Turtle populations (Brooks et al. 1992, Saumure and Bider 1998, Gibbs and Shriver 2002, Steen and Gibbs 2004, Saumure et al. 2007, Roberts et al. 2021). It is likely that a reduction in the availability of natural nest sites caused by development and succession results in increased road exposure for female Wood Turtles as they look for nesting opportunities on gravel road shoulders. Road mortality not only removes individuals from the population but often creates male-biased population sex ratios because proportionally more females are killed (Steen et al. 2006). Daigle and Jutras (2005) documented a decline of 50% for a Wood Turtle population at an agricultural site over a period of seven years in southern Quebec. Saumure et al. (2007) tracked 30 Wood Turtles in an agricultural area in Quebec from 1998 to 2000. Four of the individuals died and 90% were mutilated by agricultural equipment. Jones (2009) found that Wood Turtle mortality rates in New England were higher as a result of agricultural activities than those associated with low-intensity roads, likely because threats associated with agricultural activities were widespread (they affected a large overall area), while threats related to roads were localized.

One of the results of rapid contemporary climate change is an increase in extreme events (e.g., extreme drought and precipitation). Abnormally high precipitation can result in high-water events (i.e., flash floods), which can negatively impact adult Wood Turtle survival and recruitment. In Massachusetts, over 40% of one Wood Turtle population was displaced annually over a four-year period by flooding events, resulting in both adult mortality and reduced mating and nesting for the displaced turtles (Jones and Sievert 2009a). In Iowa, an isolated population of Wood Turtles is currently suffering complete nest losses nearly every year due to flooding (Spradling et al. 2010, J. Tamplin, University of Northern Iowa, personal communication). In addition, Mothes et al. (2020) estimated that 29%–52% of the Wood Turtle's climatic niche in the northeastern US will be lost by 2070.

Management: Given their threatened status in Wisconsin, it is illegal to harm, kill, or remove Wood Turtles from the wild, unless permitted by the WDNR. Furthermore, it is important to consider the impacts of land management activities (e.g., logging, recreational development) on known populations (Burger and Garber 1995, Compton et al. 2002, van Dijk and Harding 2011). Because Wood Turtles are such a mobile species, it is especially important to protect wide continuous corridors of riparian habitat from development and conversion to agriculture. Additional research on the sizes and types of riparian habitat buffers that are most beneficial to Wood Turtles is needed. Identification and protection of

NATURAL HISTORY BOX: Nest-Site Availability

In many areas throughout the range of Wood Turtles in Wisconsin, nesting sites are limited. This has resulted from natural succession and a lack of nest-site management. From 2007 to 2009 funds were provided to the WDNR by the American Transmission Company to survey all suitable Wood Turtle rivers and streams by canoe, walking, and driving roads that closely paralleled or crossed these waters. The surveys were conducted in seven northeastern and north-central Wisconsin counties and part of an eighth county. The goal of this work was to identify nesting sites, evaluate their condition, identify threats to each site (e.g., recreational use, natural succession of vegetation, livestock presence, agricultural use), and collect data on observed nest predation. Very few of the detected nesting sites were classified as 'natural sites' (i.e., sites that were clean sand or sandy, with some degree of sparse vegetation). Rather, the vast majority of sites actively used by turtles (i.e., evidence of at least one Wood Turtle or nest that was predated or intact) were at bridge crossings. In fact, bridge crossings and roadsides close to rivers are conservatively estimated to comprise at least 75% of the actively used nesting sites. This is particularly problematic because Wood Turtle shell fragments from old roadkill or freshly killed Wood Turtles were observed at a number of these bridge crossing sites during surveys (WDNR unpublished data). As a result of these preliminary findings, a nest-site restoration and creation program was developed by Turtles for Tomorrow, a Wisconsin nonprofit organization, to improve nesting opportunities for Wood Turtles, with the goal of reducing adult female road mortality and increasing populations. To date, 16 nesting sites have been restored or created, and 11 of these are equipped with electric fences to deter nest predators. This strategy appears effective, as no predation was detected at 9 of the 11 electrified sites, and the production of hatchlings at these locations has provided further reason for hope. For example, four nesting sites created in northwestern Wisconsin during 2014 produced 125 hatchlings the following year.

Robert W. Hay, Turtles for Tomorrow

known nesting locations from predators and poachers (Levell 2000) while also enacting habitat management strategies to combat succession are efforts that can be made toward the conservation of Wood Turtle populations (Buech et al. 1997; see Natural History Box: Nest-Site Availability).

The WDNR has experimented with several strategies to protect nests and nest sites from predation using nest cages and electric fencing, with positive results (C. Lapin, G. Kessler, and R. Hay, personal observations). Measures that have been used to reduce adult Wood Turtle mortality include installation of roadside fencing and underpasses and raising blade heights on agricultural and roadside mowers (Saumure et al. 2007, Tingley et al. 2009, van Dijk and Harding 2011, WDNR 2015d). The creation of small (≤0.4 ha [1 ac]) stream-side openings in forest canopies, particularly in areas that historically were maintained in an early successional state by natural disturbance (i.e., fire), is a management strategy that could also increase Wood Turtle foraging and nesting habitat (Ernst 2001b, Bowen and Gillingham 2004). However, this strategy should be considered carefully, including consultation with the WDNR Natural Heritage Conservation staff and compliance with WDNR regulations and would only be appropriate in areas where Wood Turtle populations already exist. We also note that Wood Turtle mortality from fire has been observed (Allard 1909). The Wood Turtle is protected by state statute in Wisconsin, so it is illegal to take or possess them, regardless of their origin, without an Endangered and Threatened Species Permit. However, if an individual turtle is encountered on a road, people are encouraged to move it off the road, so long as they do not put themselves at risk while doing so.

SPECIAL REMARKS

Wood Turtles have been reported to breed with Blanding's Turtles (Harding and Davis 1999), but whether or not the hybrid offspring are fertile is currently unknown (Scott Davis, Turtle Survival Alliance, personal communication). An adult male turtle that possessed characteristics of both species, consistent with hybridization, was captured in southern Jefferson County in 2017 (see Figure 330 in the Blanding's Turtle, *Emydoidea blandingii* species account).