Over-wintering Characteristics of West-Central Wisconsin Blanding's Turtles, *Emydoidea blandingii*

RICHARD P. THIEL[1] and TIMOTHY T. WILDER[2]

[1]Wisconsin Department of Natural Resources, Sandhill Wildlife Area, 1715 Hwy X, Babcock, Wisconsin 54413 USA
[2]Department of the Army, Directorate of Public Works, IMNE-MCY-PWEN, 2171 South 8th Avenue, Fort McCoy, Wisconsin 54656-5136 USA

Thiel, Richard P. and Timothy Wilder. 2010. Over-wintering characteristics of west-central Wisconsin Blanding's Turtles, *Emydoidea blandingii.* Canadian Field-Naturalist 124(2): 134–138.

Hibernation of adult-sized Blanding's Turtles was studied at two west-central Wisconsin sites between 1991 and 2008. Turtles arrived at hibernacula from mid September to early October, spending 126 to 216 days at these sites, and generally emerged in early April yearly. Sixty percent of females and 30 percent of males hibernated in natural over man-made structures as hibernation sites. Anoxic conditions near five hibernation sites ranged from 78 to 100 days. Shell temperatures of three turtles monitored over five winters remained at <1°C a mean of 2,274 hours each winter. Over the same period, four turtles' temperatures were between 0° and -1°C a mean of 302 hours. During the course of our study, hibernating west-central Wisconsin Blanding's Turtles demonstrated a remarkable degree of both cold and anoxia-tolerance similar to that observed among Painted Turtles (*Chrysemys picta*) and Snapping Turtles (*Chelydra serpentina*).

Key Words: Blanding's Turtle, *Emydoidea blandingii*, anoxia, cold tolerance, hibernation, dissolved oxygen, Wisconsin.

Blanding's Turtles (*Emydoidea blandingii*) are a northern temperate-distributed freshwater turtle species presently experiencing anthropogenic-caused, range-wide population declines (Schuler and Thiel 2008, Ernst et al.1994). Over their long life spans Blanding's Turtles experience widely varying winter weather conditions of unpredictable lengths in which they must hibernate. Wisconsin winters includes periodic freeze-thaw cycles, deep cold, snow and ice accumulations that frequently penetrate well into bottom sediments and deny turtles hibernating in shallow marsh basins access to atmospheric oxygen. The extreme variables of winter weather from year-to-year are a challenge to turtles. In Wisconsin the number of turtle species decreases from eleven in the south to only four in the north – a decrease of more than 60 percent in species diversity within a 450 km north-south gradient (Vogt 1981).

When we began our monitoring activities on Blanding's Turtles in the early 1990's, little information was available on physiological mechanisms of hibernating northern temperate turtle species (Jackson 1979). Two physiological over-wintering strategies are presently recognized among northern freshwater turtles: those that are anoxia-intolerant (death < 50 days), and those that are anoxia-tolerant (death > 100 days) (Ultsch 2006, Ultsch and Reese 2008). Even within a species, tolerance among individuals varies by locality. Reese et al. (2004) demonstrated that Painted Turtles displayed varying tolerance to anoxia depending on whether individuals were from the northern or southern edge of their continental range.

Ultsch (2006) believed that Blanding's Turtles are anoxia-tolerant because they share similar over-wintering habitats with Snapping and Painted Turtles. The species' winter metabolic rate (oxygen demand) is reported to be between the values of Painted and Snapping Turtles (Graham and Butler 1993). Kofron and Schreiber (1985) reported two adult Blanding's Turtles remained somewhat active in winter in their Missouri study site near the southern portion of the species' range, moving by as much as 13 m at water temperatures of 6.2-7.5°C at depths of 9-21cm in mud in a Missouri marsh. Once water temperature dropped to 2-3°C, weekly locations declined to 1-2 m. This contrasts with the relative lack of movements observed among Blanding's Turtles in mid-winter from Nova Scotia and Ontario (Newton and Herman 2009, Edge et al. 2009). These observations from the southern, eastern and northern edges of the Blanding's Turtle's continental range show that the species exhibits tolerance to cold water temperatures during hibernation, eliminating movements at very cold temperatures.

We report on various aspects of hibernation observed among Blanding's Turtles studied in west-central Wisconsin over a 2-decade period. We were interested in assessing the ratio of man-made to natural hibernation sites in our human-modified landscapes. We also document the duration, in days, Blanding's Turtles spent at hibernation sites by comparing late autumn and early spring sightings and captures of Blanding's Turtles to radio telemetry data on arrival and departure dates from hibernation sites. We compared this to data from several turtles outfitted with thermal data loggers to refine our estimates of the duration of hibernation among Blanding's Turtles in central Wisconsin. We report on Blanding's Turtle tolerance to near-freezing conditions, and dissolved oxygen levels at a small number of hibernation sites to assess Blanding's Turtle tolerance to anoxic conditions.

We hypothesized that Blanding's Turtles would show avoidance of man-made sites to hibernate in; that duration spent at hibernation sites would exceed 120 days; and that Blanding's Turtles would display tolerance similar to that of Painted Turtles and Snapping Turtles to both near-freezing and anoxic conditions.

Methods

Winter weather: Long-term average monthly temperatures at Wisconsin Rapids, located 50 km east of SWA were: September, 15°C; October, 8.3°C; November, 0°C; December, -7°C; January -10°C; February, -7°C; March -0.5°C; and April 7°C (NOAA*). Ice and snow covered Blanding's Turtle hibernation sites generally from mid-December to late March for the duration of the study at SWA (Thiel, unpublished notes).

Sandhill Wildlife Area (SWA): is a 3,884 hectare facility, located in west-central Wood County, Wisconsin (Latitude 44°, 17'; Longitude 90°, 10') containing approximately 50 percent upland forests of *Quercus* spp., *Populus* spp. and scattered pine *Pinus* spp. Wetlands consist of a variety of man-made flowages, ranging from 35 to 1,200 ha. Predominant vegetation consists of *Sphagnum* spp., sedges, rushes, bluejoint grass (*Calamagrotis canadensis*), and *Salix* spp. and *Spirea* spp. on drier sites. Water levels are regulated by bulkheads on inter-connecting ditches, and recharge is primarily through precipitation.

Blanding's Turtles were captured and marked between 1991 and 2008 as staff was conducting other field work. In 1997, 1998, and 2002 Blanding's Turtles were also captured on SWA using hoop nets baited with dead fish. Between 2001 and 2008 evening nesting surveys were run on SWA to encounter adult female Blanding's Turtles. Between one and four turtles were radioed and monitored each year from those that were captured annually.

Fort McCoy Military Installation (FMMI): is a 22,184 hectare military installation, located in north-central Monroe County, Wisconsin, Latitude 44°, 0'; Longitude 90°, 40', containing approximately 93 percent upland forests of *Quecus* spp., *Pinus* spp., *Acer rubrum*, and *Populus* spp. Wetlands consist of 11 man-made ponds and flowages ranging in size from 1.2 ha to 100.0 ha. Additionally, there are 114.6 km of streams on the installation. Predominant vegetation consists of *Sphagnum* spp., sedges, tag alder (*Alnus incana*), and poison sumac (*Rhus vernix*). In all but one flowage, water levels are regulated through precipitation and ground water recharge.

Between 1999 and 2008 surveys were conducted on FMMI by walking marsh and stream edges searching for and capturing Blanding's Turtles that had recently emerged from hibernation. From 2001 to 2006, Blanding's Turtles were also captured on FMMI using hoop nets and wire mesh turtle traps baited with dead fish.

Captured turtles were weighed to the nearest 1.0 g using a triple beam-balance scale at SWA and a digital scale at FMMI. Each was sexed, and series of coded marginal scutes were filed to individually mark each (Cagle 1939). Blanding's Turtles were considered adult with carapace lengths in excess of 191 mm (Thiel, unpublished notes).

Radio transmitters (Advanced Telemetry Systems, Model R1930, Isanti, MN) were glued to the left or right anterior portion of the carapace of 2–5 Blanding's Turtles annually beginning in 1993 at SWA and 2000 at FMMI. Turtles were located at one or two week intervals throughout the summer foraging season and into autumn until movements ceased. Each winter radioed turtles were located twice monthly at SWA; once or twice during winter at FMMI after movements ceased. Therefore our comments on winter movement are restricted to SWA. In mid to late March radioed turtles' hibernation sites were visited at least twice weekly to determine date of first emergence. With one sole exception, turtles at these sites were not disturbed.

We defined over-wintering as the period of time, in days, that radioed turtles' movements ceased (< 2m).

Hibernation sites were categorized as man-made structures, including dikes, drainage ditches, hand dug ditches and borrow pits. Natural sites included Beaver (*Castor canadensis*) channels, open water including those in man-made flowages, emergent vegetation and riverine environments. We did not conduct micro-habitat evaluations of hibernation sites. Fidelity to over-wintering sites was assessed for individual radioed Blanding's Turtles monitored greater than one winter period.

We calculated the range, in days, between latest autumn and earliest spring visual observations of Blanding's Turtles, and the range, in days, between arrival and departure of radioed turtles from their hibernation sites. A date was assigned mid-way between two succeeding locations for radioed turtles if the exact arrival / emergence date was unknown. Events spanning greater than 20 days (± 10 days) were censored. Median autumn arrival and spring departure dates were determined from pooled radio telemetry data because we had insufficient sample sizes for individual winters. Hibernation, in days, was calculated by summing the days between the median dates of arrival and emergence for all radioed turtles.

A small number of radioed turtles were outfitted with a HOBO® TidbiT®[1] thermal recorder glued to the carapace adjacent to the transmitter. We interpreted a spike of greater than 2.5°C within a single two-hour interval as basking behavior, and calculated the duration of hibernation, in days, between the latest logged autumn and earliest spring basking event.

[1] Onset Computer Corporation, 470 MacArthur Blvd., Bourne, Massachusets 02532 USA

Thermal regimes of radioed hibernating turtles were assessed in winters 1997-98, 1998-99, 1999-2000 and 2000-01. These were considered accurate to within 0.5°C. TidbiTs® were calibrated to record temperature at one hour intervals in winter 1997-98. Thereafter they were calibrated at two hour intervals. TidbiT® loggers retrieved in spring were down-loaded to an excel spreadsheet. We determined the number of individual events and interval lengths (hours per event) turtle exterior shell temperatures reached or fell beneath 1°C and also between 0 and -1°C.

Dissolved oxygen (DO) (mg/L) was obtained at irregular intervals by drilling a hole through the ice and extracting a water sample within one meter of five radioed hibernating SWA turtles (representing 6 turtle-winters) in winters 1993-94 (n=1 turtle), 1994-95 (n=3 turtles) and 1995-96 (n=2 turtles). Accuracy in our analysis was 0.5mg/L. We used Newton and Herman's (2009) definition of anoxia as DO levels of 0 and calculated the minimum number of days radioed turtles were at hibernation sites with DOs recorded as 0.

Statistica ® was used to perform χ^2 analyses of differences between use of man-made vs. natural environments between males and females; re-use of man-made vs. natural environments between males and females; re-use of sites; and re-use of sites by all females sampled vs. females with a minimum of three consecutive winters of hibernation site data. T-tests were used to analyze the range, in days, that SWA vs, FMMI turtles remained at sites; the range, in days, that females remained at sites; and to determine whether the greater length of time SWA females spent at hibernation sites was truly different than females at FMMI. Significance was accepted at $P < 0.05$.

Results

Ratios of Man-Made vs. Natural Sites

We tallied 44 hibernation sites used by 19 female Blanding's Turtles (14 FMMI; 5 SWA) monitored a mean of 2.1 winters (range 1 to 5 winters), and 27 hibernation sites used by 13 male Blanding's Turtles (3 FMMI; 10 SWA), monitored a mean of 2.1 winters (range 1 to 7 winters). Female selection of natural overwintering sites (60 percent, 26 vs. 18) differed significantly from males (30 percent, 8 vs. 19)(χ^2; df = 1; $P = 0.03$). Thirty-two percent of females and 60 percent of males re-used former sites (but not necessarily in consecutive winters). This was not significant (χ^2; df = 1; $P = 0.23$). Frequency of re-use of natural sites did not differ between genders (20 percent for females vs. 50 percent for males; χ^2; df = 1; $P = 0.95$).

Arrival and Emergence Dates

Arrival at hibernation sites from autumn observations and capture samples ranged from 17 September to 10 November. At SWA 10 radioed males and 5 radioed females (30 combined events) arrived at hibernation sites from 1 September to 18 November with a calculated median entry date of 24 September. Arrival dates for 2 radioed FMMI males and 12 radioed females (16 events) was 1 September to 6 November with a calculated mean arrival date of 19 October.

Emergence dates from spring observations and capture samples ranged from 26 March to 9 May. Emergence dates of 9 SWA radioed males and 4 radioed females (27 combined events) ranged from 26 March to 20 April with a median date of 9 April. Emergence dates for 2 FMMI radioed males and 8 radioed females ranged from 28 March to 20 April, with a median date of 6 April.

Duration at Hibernation Sites

The interval between median arrival and departure dates among late autumn (n=21) and early spring (n=65) observations and captures of Blanding's Turtles was 198 days. The interval between median arrival (n=25) and emergence dates (n=16) among radioed SWA turtles was 197 days, in contrast to a span of 166 days between median arrival and emergence dates among radioed FMMI turtles.

Entry and emergence dates within a single winter were known for 10 individual radioed male SWA turtles, and these averaged 181 days (range:147 – 211 days) in contrast to two radioed FMMI males who averaged 164 days (range:153-174 days). This difference was not significant (t-test; df = 2; $P = 0.15$). Five radioed SWA females averaged 185 days (range:163 – 216 days) and 7 radioed FMMI females averaged 171 days (range:153–195 days). This difference approached significance (t-test; df = 9; $P = 0.058$). Combining males and females and comparing between the two study sites, duration at hibernation sites was significantly greater at SWA (t-test; df = 29; $P = 0.02$). Duration of hibernation from one female and two males wearing TidbiT® thermal loggers (totaling 5 winters) ranged from 126 to 187 days, and averaged 165 days.

Radioed SWA females remained inactive at hibernation sites an average of 15.75 days longer (range, 6-29 days) than males in the same winter ($n = 5$ winters). Similarly a single radioed FMMI female remained inactive 24.5 days longer than two males over the same winter, but the difference between the SWA and FMMI values was not significant (t-test; df = 2; $P = 0,27$). When we combined the two study sites, the duration of females was significantly greater than males (t-test; df = 10; $P = 0.048$).

Anoxia

Anoxic conditions were reached between 5 December and 10 January (median = 23 December) in the vicinity of hibernation sites of four turtles, and re-oxygenation occurred between 13 March and 3 April (median = 24 March) (Table 1). Using the latest autumn and earliest spring dates and comparing this to median dates for all recorded events, the length of time Blanding's Turtles endured anoxic conditions ranged from 78 to 100 days and averaged 87 days.

Cold Tolerance

Shell temperatures were monitored on three Blanding's Turtles a total of five winters. In winter 1997-98, when TidbiT® loggers were calibrated at one hour intervals, shell temperatures were recorded an average of 166 days per winter (n=12,156 hourly events). Thereafter loggers were calibrated at two hour intervals, recording an average of 204 days per winter (*n*=7, 329 2-hour events).

Loggers placed on three Blanding's Turtles accumulated 19 485 h of temperature data (five Blanding's Turtle winters) and recorded 109 events below 1°C. Each turtle averaged 22 events (range 13 to 31) and an average of 2,274 hours (58 percent of 19,485 h; range 1604 to 3202 h) below 1°C per winter. Individual events lasted an average of 98 h (range 1 to 1848 h).

Temperatures between 0 and -1°C were recorded in 26 events (average = 26; range 15 – 80) averaging 302 hours per winter per turtle (1.5 percent of 19 485 h.; range 60 to 756 h. Individual turtles averaged 6.5 events (range 0 – 80) lasting an average of 11.6 h (range 1 to 74 h).

Discussion

Ratios of Man-Made vs. Natural Sites

Unlike the study sites of both Edge et al. (2009) and Newton and Herman (2009) much of the Blanding's Turtle's continental range today occurs in human-dominated landscapes. Blanding's Turtle habitat in our study sites has been manipulated by humans. The species readily used man-made or man-modified structures to hibernate in, although males were more likely than females to use such areas.

Approximately 50 percent of the Algonquin Provincial Park, Ontario turtles returned to the same hibernation site in the following winter (Edge et al. 2009). In Central Wisconsin, 33 percent of radioed turtles returned to the same site in the following winter. However, we had the opportunity to observe some turtles for more than two consecutive winters and re-use of former sites was variable. Over a five-winter period FMMI female 4BDFM99 used a road-side borrow pit in two consecutive winters but different sites in subsequent winters. Five different sites were used by SWA female 75 over a seven-winter period; including two separate sites used two consecutive years each. SWA male 188 used the same borrow pit over five consecutive winters. The tendency to re-use previous hibernation sites is likely reduced, considering that SWA turtles had greatly altered home ranges from year-to-year (Schuler and Thiel 2008).

Duration of Inactivity at Over-Wintering Sites

Blanding's Turtles in west-central Wisconsin arrive at hibernation sites between mid September and late October. Our arrival dates agree with observations of Newton and Herman (2009) from Nova Scotia (September to mid-November), and Edge et al. (2009) from Ontario (October). Newton and Herman (2009) reported their Blanding's Turtles moved locally 5 to 15 m within the mid-winter period. Movements were positively correlated with warmer water temperature. Edge et al. (2009) noted that turtles moved little in winter following ice formation, remaining beneath at least 10 cm of free water. By contrast, SWA turtles seldom moved after arriving at their hibernation sites in September or October.

Our emergence dates ranged from 28 March to 20 April. This coincides with observations of emergence from Nova Scotia (Newton and Herman 2009) of late March to mid April, and between 11 and 14 April from Ontario (Edge et al. 2009). An exceptionally late case occurred on 9 May when a basking turtle was encountered in a SWA marsh. Inspecting the site we discovered a matrix of frozen and thawing sediment extending down 20 cm overlaying a thawed matrix 25 cm thick that lay on top of a completely frozen layer of sediment of unknown depth. We felt this turtle had just managed to extricate itself from this partially thawed substrate.

Blanding's Turtles in our study areas spent from 126 to 216 days at hibernation sites each winter. Our TidbiT® thermal data indicated that Blanding's Turtles spent an average 164 days inactive at hibernation sites. This is nearly a month longer than the 101 to 136 days reported for the species in Ontario (Edge et al. 2009). Males in our study area tended to arrive later than females each autumn, and their duration of hibernation was shorter. The variation in duration exhibited by our turtles reflect the Blanding's Turtle's capacity to endure highly variable winter lengths.

Anoxia and Cold Tolerance

Newton and Herman (2009) and Edge et al. (2009) demonstrated that Blanding's Turtles are hypoxic-tolerant, inhabiting sites with DOs ranging from 2.8 to 11.3 mg/L in Nova Scotia and 2.6 to 3.4 mg/L in Ontario, respectively. At the latter site, turtles were denied access to atmospheric oxygen for periods ranging from 101 to 136 days because of ice. Anoxia conditions in the vicinity of SWA Blanding's Turtle hibernation sites ranged from 78 to 100 days and averaged 87 days. This corresponds with the average of 95 days spent by five SWA turtles at temperatures of less than 1°C.

In SWA ice was present from early December to late March each year (Thiel, unpublished notes). At several hibernation sites with autumn surface water depths of 10-25 cm no liquid water existed extending 10 cm into the underlying sediment column by January so DOs could not be measured. Blanding's Turtles could not move in response to extremely cold or anoxia conditions. This contrasts to winter movements of Blanding's Turtles in Missouri and Nova Scotia (Kofron and Schreiber 1985; Newton and Herman 2009). These were not isolated cases. SWA female 39 hibernated in a one hundred year old, sediment filled, hand-dug ditch in the relatively snow-free winter of 1994-

TABLE 1. Length, in days, of anoxic conditions at Blanding's Turtle hibernation sites.

Turtle	Year	Anoxia reached… between		median	Re-oxygenated... between		Median	Days between Medians
36M	1993-94				16 March	24 March	20 March	
16M	1994-95	3 January	10 January	07 January	16 March	03 April	25 March	78
39F	1994-95	5 December	21 December	13 December	13 March	02 April	23 March	100
58M	1995-96	22 December	10 January	01 January				
23F	1995-96	22 December	10 January	01 January	20 March	26 March	23 March	82
							Average =	87

95. Between at least 3 January and 13 March solid ice extended into the sediment and no liquid water remained at the hibernation site. On 2 April the ice was gone and the turtle was located alive. She survived hibernating in a micro-environment, incapable of escaping, a minimum of 77 days near freezing, and 100 days in an anoxic condition (Table 1).

In 66 turtle-winters of data accumulated in this study, only one death (1.5 percent) was attributed to complications associated with hibernation. Although not autopsied, we speculated this FMMI Blanding's Turtle suffered tissue damage caused by freezing. At ice-up maximum water depth was approximately 60 cm at her hibernation site. A lack of snowfall during the winter allowed frost to penetrate deeper than normal into the soil. When located on April 28, she was found dead in 30 cm water within a few meters of her hibernation site. She had evidently aroused from hibernation but had expired shortly thereafter.

Our data corroborate the findings of both Newton and Herman (2009) and Edge et al. (2009) that Blanding's Turtles are both freeze and anoxia-tolerant similar to Painted and Snapping turtles (Ultsch 2006; Ultsch and Reese 2008). Blanding's Turtles are well suited to endure the widely variable winter lengths experienced at these latitudes, clearly important for a species occupying the northern fringe of Testudine distribution within North America.

Acknowledgments

We thank Matt Schuler for performing the statistical analyses and numerous high school students, staff and volunteers for their efforts in monitoring Blanding's Turtles at both SWA and FMMI.

Documents Cited (marked * in text)

National Oceanic and Atmospheric Administration. http://www.crh.noaa.gov/images/grb/data/climate/dnorms/DRWISCONSINRAPIDS.xls. Accessed 14 December 2009.

Literature Cited

Cagle, F. R. 1939. A system for marking turtles for future identification. Copeia 1939: 170-173.

Edge, C. B., B. D. Steinberg, R. J. Brooks, and J. D. Litzgus. 2009. Temperature and site selection by Blanding's turtles (*Emydoidea blandingii*) during hibernation near the species' northern range limit. Canadian Journal of Zoology 87: 825-834.

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

Graham, T. E., and **B. O. Butler.** 1993. Metabolic rates of wintering Blanding's turtles, *Emydoidea blandingii.* Comparative Biochemistry and Physiology 106A: 663-665.

Jackson, D. C. 1979. Respiration. Pages 165-191 *in* Turtles: perspectives and research. *Edited by* John Wiley and Sons, New York.

Kofron, C. P., and **A. A. Schreiber.** 1985. Ecology of two endangered aquatic turtles in Missouri: *Kinosternon flavescens* and *Emydoidea blandingii*. Journal of Herpetology 19: 27-40.

Newton, E. J., and **T. B. Herman.** 2009. Habitat, movements, and behavious of overwintering Blanding's turtles (*Emydoidea blandingii*) in Nova Scotia. Canadian Journal of Zoology 87: 299-309.

Reese, S. A., E. R. Stewart, C. E. Crocker, D. L. Jackson, and **G. R. Ultsch.** 2004. Geographic variation of the physiographic response to overwintering in the painted turtle (*Chrysemys picta*). Physiological and Biochemical Zoology 77: 619-630.

Schuler, Matthew, and **Richard P. Thiel.** 2008. Annual vs. multiple – year home range sizes of individual Blanding's turtles, *Emydoidea blandingii*, in central Wisconsin. Canadian Field-Naturalist 122: 61-64.

Ultsch, Gordon R. 2006. The ecology of overwintering among turtles: where turtles overwinter and its consequences. Biological Reviews 81: 339-367.

Ultsch, Gordon R., and **Scott A. Reese.** 2008. Ecology and physiology of overwintering. Pages 91-99 *in* Biology of the Snapping Turtle (*Chelydra serpentina*). *Edited by* A. C. Steyermark, M. S. Finkler and R. J. Brooks. The Johns Hopkins University Press. Baltimore, Maryland.

Vogt, R. C. 1981. Natural history of amphibians and reptiles of Wisconsin. The Milwaukee Public Museum, Milwaukee, Wisconsin. 205 pages.

Received 15 December 2009
Accepted 23 July 2010