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Blanding's Turtles from the Western Sandhills of Nebraska

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BLANDING'S TURTLES FROM THE WESTERN SANDHILLS OF NEBRASKA

A Thesis

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Abstract

In all states and provinces in which they reside, Blanding's Turtles (*Emydoidea blandingii*) are listed as a species of conservation concern. In other parts of their range, Blanding's Turtle populations have experienced declines and are threatened by habitat fragmentation and degradation of wetlands. Nebraska is the only state that considers the species to be secure. The largest known population of Blanding's Turtles was recorded in the Sandhills of Nebraska. The Sandhills represent both the largest sand dune complex in the northern hemisphere and the largest intact temperate grassland ecosystem remaining in the world. These features likely attribute to the success of this species in the state. The Sandhills are one of the last strongholds for Blanding's Turtles, and few studies have focused on the species in this region. Our study builds upon this knowledge and serves as an important benchmark for the status of Blanding's Turtles in the Sandhills. In Chapter 1, we discuss demographic attributes, trapping results, space use, and other natural history of a population of Blanding's Turtles at the westernmost edge of the species' range. We appear to be the first to report relative abundance and locations of overwintering sites of Blanding's Turtles in Nebraska. Chapter 2 highlights other writings about Blanding's Turtles that were completed during my graduate study. Results of this study can be used to align land management practices with Blanding's Turtle conservation strategies.

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Chapter 1. Blanding's Turtles from the western Sandhills of Nebraska

Abstract

Blanding's Turtles (*Emydoidea blandingii)* occur disjunctly from southeastern Ontario to southern Nova Scotia, south to the New England states, and west through the Great Lakes to Minnesota, Iowa, and Nebraska. In most states and provinces where this species resides, populations are considered endangered, threatened, or in decline. Across its range, Blanding's Turtles have shown variation in demographics and other ecological traits. Detailed assessment of this variation is important for local management of the species. This study provides baseline data of Blanding's Turtles in grasslands of the Sandhills of Nebraska at the extreme western edge of the species distribution. Demographics, space use, trapping efforts, and natural history of Blanding's Turtles were examined at Fawn Lake Ranch, located in Cherry County, Nebraska. Thirty-three individual Blanding's Turtles were captured (8 females, 7 males, and 18 juveniles) from 25 May 2019 to 25 September 2020. There were no significant differences detected in mean weight, carapace length, carapace width, shell height, or plastron length between adult females and males. Weights of all individuals were highly correlated with carapace lengths. Trap type influenced size of turtles captured, with larger Blanding's Turtles captured in hoop traps compared to crab traps. Home range analyses were performed on 13 individuals (7 females, 5 males, and 1 juvenile) in ArcGIS. Home ranges were calculated using the Minimum Convex Polygon method. Home range sizes did not differ significantly between sexes. Accounts of Blanding's turtles out of water, long-distance

movements, and overwintering sites also were documented in this study. Body size measurements fell within the ranges of other studies. Mean home range sizes were larger than in some populations outside of Nebraska. From May to August, some Blanding's Turtles were located on land within vegetation at wetland edges. Buffers around wetlands may need to be considered when ranch management practices occur.

Introduction

The distribution of Blanding's Turtles (*Emydoidea blandingii*) is restricted to southeastern Ontario to southern Nova Scotia, south to the New England states (New York, Massachusetts, New Hampshire, Pennsylvania, and Maine) and west through the Great Lakes, Minnesota, Iowa, and Nebraska (Congdon et al. 2008; Ernst and Lovich 2009; COSEWIC 2016). Blanding's Turtles are more abundant near the western edge of their wide-ranging distribution in North America. A population of 130,000 individuals was reported at nearby Valentine National Wildlife Refuge in the early 2000s (Lang 2004). The second largest population, with over 5,000 individuals, is within the upper Mississippi River flood plain of southeastern Minnesota (Pappas et al. 2000). Throughout most of its range, *E. blandingii* is listed as a species of local conservation concern (Congdon and Keinath 2006; COSEWIC 2016). Blanding's Turtles are considered secure in Nebraska but are managed as high-risk based upon their vulnerability in other areas (Congdon and Keinath 2006; COSEWIC 2016; Schneider et al. 2018, Panella and Rothe-Groleau 2021). Habitat destruction and degradation threaten small, disjunct populations of *E. blandingii* at every stage of their life cycle throughout its distribution (Lang 2004; Congdon and Keinath 2006; Congdon et al. 2008; COSEWIC 2016).

Relatively few studies have focused on *E. blandingii* in Nebraska. The largest known population from the species' entire distribution is at Valentine National Wildlife Refuge (VNWR) in northeastern Cherry County and was estimated to be at least 137,000 individuals (Lang 2004). Lang (2004) studied demographic and reproductive characteristics, seasonal movements, and road mortality at VNWR in 2002 and 2003.

Effectiveness of conservation efforts (e.g., fences and culverts) was studied along roadways at VNWR (Huijser et al. 2017). Bury and Germano (2003) used radio telemetry to describe habitat use by *E. blandingii* and Northern Painted Turtles (*Chrysmys picta*) at VNWR. Previously, Germano et al. (2000) estimated growth rates and age and size structure of the VNWR population. Reproductive characteristics, body size, and growth rates were reported from Grant and Arthur counties (Rowe 1992). Ruane et al. (2008) also reported demographic and reproductive traits for *E. blandingii* in Grant County. A recent observation in Sheridan County extended the species' known distributional range westward (Forrester et al. 2018). In general, Blanding's Turtles are uncommon in northeastern and eastern Nebraska, but common in the Sandhills (Ballinger et al. 2010; Fogell 2010). A conservation assessment for *E. blandingii* in Nebraska listed the species as a Tier 1 at-risk species, the highest ranking in the state (Schneider et al. 2018).

From a local standpoint, continued monitoring is needed to ensure that Blanding's Turtle populations are remaining secure in Nebraska. On a larger scale, understanding features that aid in the success of Blanding's Turtles in Nebraska could inform conservation strategies elsewhere. This study described demographic attributes, trapping results, space use, and other natural history notes for a population of *E. blandingii* at the westernmost edge of its distribution in the Sandhills during a two-year study. Relative abundance of Blanding's Turtles and locations of overwintering sites appear to have been reported for the first time in our study. Here, at the highest elevation and coldest region of its distribution, *E. blandingii* experience a continental climate, with hot summers and cold winters (Bleed and Flowerday 1998). About 78% of annual precipitation occurs as

rain during the spring and summer months (April to September) (Sherfey et al. 1965). To our knowledge, the last in-depth study of *E. blandingii* in the Sandhills was more than 15 years ago in Grant County (Ruane et al. 2008). Our study serves as an important benchmark for the status of *E. blandingii* populations in the western Sandhills of Nebraska, a landscape considered to be among the last strongholds for the species (Panella and Rothe-Groleau 2021). Results also will inform land management practices that consider Blanding's Turtles conservation on a private ranch managed for bison production.

Methods

Study site

We conducted research in the western region of the Nebraska Sandhills. The Sandhills encompass approximately 4,998,677 hectares of sand dunes that were stabilized by prairie grasses in north-central Nebraska and extreme southern South Dakota (Bogan 1995, Bleed and Flowerday 1998). The Sandhills are sparsely populated by people, and a mosaic of upland sand dunes and wetlands supports *E. blandingii* throughout its life cycle. Interdunal valleys contain freshwater marshes, wet prairies, small tributaries, and fens that provide habitat for Blanding's turtles (Panella and Rothe-Groleau 2021). Dominant grasses in the uplands include prairie sand reed (*Calamovilfa longifolia*), sand dropseed (*Sporobolus cryptandrus*), sand bluestem (*Andropogan hallii*), and switchgrass (*Panicum virgatum*) (Bogan 1995; Kaul et al. 2012). Forbs, cacti (Cactaceae), and yucca (*Yucca glauca*) also occur throughout the dunes (Bogan 1995). Rushes (Juncaceae) and

spikerushes (*Eleocharis*) are common in marshes and wet meadows (Bogan 1995). Dense patches of duckweed (*Lemna*), cattails (*Typha*), coontail (*Ceratophyllum*), bladderwort (*Utricularia*), horsetail (*Equisetum*), sand bar willow (*Salix*), and smartweed (*Polygonum*) occurred in aquatic habitats at our study sites.

Blanding's Turtles were studied on a private bison ranch southeast of Gordon in Cherry County, Nebraska (42°29'56.33" N, 101°54'7.00" W) (Appendix A). This approximately 25,815-hectare area consisted of a mosaic of wetlands, wet meadows, and upland sand dunes positioned at the westernmost edge of the species' range (Forrester et al. 2018). Many wetland complexes contained muskrat (*Ondatra zibethicus*) structures (houses and platforms) that served as basking sites for turtles. Some wetland habitats had been altered to divert water, such as with drainage ditches and culverts. The property had been managed with bison since 2005, and previously with cattle (John Halstead, personal communication). Few roads were present on the landscape, as past cattle operations moved livestock mostly on horseback.

We studied Blanding's Turtles in both a wet (2019) and a dry year (2020). There were no weeks of drought recorded in Cherry County from 1 May 2019 to 31 August 2019. For that same period in 2020, Cherry County recorded 10 weeks of drought (U.S. Drought Monitor n.d.). Total precipitation recorded from 1 May to 31 August near Mullen, NE, was 54.6 cm (21.5 in) in 2019 compared to 30.2 cm (11.9 in) in 2020 (Station: Cher1885; Mullen 7.84 NNE; NeRain n.d.).

Trapping and catching

We trapped turtles from 15 May to 18 September 2019 and from 27 May to 15 August 2020. We used three types of traps: small crab (n = 8), large crab (n = 21), and hoop (n = 10). Each trap was referred to by a number engraved on a metal tag. Small and large crab traps (Promar Collapsible Crab/Fish/Crawdad Trap 24 x 18 x 8 in [model number TR-101] and 32 x 24 x 11 in [model number TR-102W], Promar Inc., Gardena, CA) were modified slightly to allow turtles with tall carapaces to enter traps. We cut a few connective strings on entrances of both ends of traps, as openings were tight and appeared likely to preclude turtle entry on the bases of simulating turtle entry with our hands. Crab traps were placed in shallow water near the shoreline. Hoop traps (Turtle Net, 2-1/2 ft. diameter, 1-1/2 in. sq. mesh (model number TN215; Memphis Net & Twine Co., Inc., Memphis, TN), which were not modified in 2019, but were modified in 2020 (see below), were placed in deeper water ($\leq$ 0.6 m) and held upright with metal rebars to ensure traps remained open and functional. We focused trap placement near vegetated cover and muskrat structures where turtles frequently basked. When available, natural leads such as roads and fences were used to help guide turtles towards traps. We ensured all traps had about 15 cm of air exposure to allow animals to breathe (Hasler et al. 2015). Each trap was baited with one 3.75 oz. (~28 g) can of Brunswick® sardines in soybean oil. Bait was changed every three days. In events of wetland flooding, traps were removed promptly after storms had passed. We recorded information about specific trap placement at each site. Traps were left at sites from 1 to 13 days and checked at least once every 24 hours. At the conclusion of each trapping session, date and the time traps

were removed were recorded to calculate total number of trap days (e.g., trap set on 15 May and removed 20 May = 5 trap days).

In the 2020 field season, we modified some traps to possibly limit turtles from escaping traps. We modified three traps of each trap type. We attached three-hole punched, clear plastic sheets to the top of the entrance of some traps using metal swivel clips. Two plastic sheets covered entrances of crab traps, as the openings were wide, and one plastic sheet was used for hoop traps. Round fishing weights reinforced with 5-min epoxy were placed at bottoms of plastic sheets to keep plastic from floating. To test whether trap modifications prevented escape and/or attracted other Blanding's Turtles, a single Blanding's Turtle was placed in a modified trap of one trap type (hoop, large crab, or small crab) for a fixed amount of time (e.g., 17 to 57 hours) before the same or other individual was placed in an unmodified trap of the same trap type with a similar habitat (e.g., submerged vegetation) for an equal amount of time. Time periods in modified and unmodified traps were not always equivalent because some turtles escaped. Blanding's Turtles involved in this experiment were captured opportunistically via traps and actively via telemetry for temperature logger device adherence. In addition to turtles in traps, some individuals were captured opportunistically by hand throughout the field site.

Site descriptions

We recorded descriptive information about each wetland the day traps were set or the following day. We described each wetland in relation to semi-permanent landscape features (e.g., direction to road, windmill). An offline map application, Avenza® Maps,

was referenced to describe these features. Vegetation surrounding sites also was described (e.g., grassland, woody vegetation). Presence of emergent vegetation and aquatic cover (floating or submerged vegetation, moss, and/or algae) was noted. Substratum was described as soft (boot sinks), medium (slightly squishy), or hard (does not move when walked upon). Presence of muskrat structures was noted. Representative photos of sites were taken, including views in each cardinal direction. We determined the approximate area of wetlands, with smaller wetlands measured in-situ using a rangefinder (RX-1200i, Leupold and Stevens Inc., Beaverton, OR), and areas of larger wetlands estimated using Google Earth (image date 9 September 2016). A detailed sketch of each site was completed that included locations of traps, photo point, muskrat structures, and areas with emergent vegetation. We repeated site descriptions at the start of each trapping session to track changes in wetland water levels, vegetation, and muskrat structures.

At time of trap placement and during subsequent visits to check traps, we recorded temperature and counts of turtles observed inside and outside (e.g., basking) of traps. Water temperature was taken with an analog thermometer in the field. Most air temperature readings were obtained from a weather station located at the ranch headquarters, but some air temperatures were obtained in the field. We also recorded additional notes (e.g., descriptions of photos taken). Data sheets for site descriptions as well as other data collected during the project are included in Appendix B.

Measurements and marking

We recorded the number of turtles of each species captured in traps. For each Blanding's Turtle, we recorded body weight and external measurements. Weights of individuals were recorded in grams (Pesola scales various sizes, Schindellegi, Switzerland). Carapace and plastron lengths and widths were recorded by measuring straight-line distances using a ruler and large dial calipers (Codimex-L 40 cm, Forestry Suppliers Inc., Jackson, MS) to the nearest millimeter. Height was measured as the straight-line, vertical distance from the tallest point of the carapace to the bottom of plastron near the hinge.

Ages of Blanding's Turtles were estimated by counting growth rings (annuli) on the pectoral scute of the plastron. If we were unable to count annuli due to worn scutes, then annuli number was recorded as not applicable. Adult turtles were sexed based on a combination of age, size, and external morphological traits. For turtles with fewer than 12 annuli, individuals were recorded as juveniles with sex unknown. Turtles were considered juveniles if they had a carapace length < 180 mm. In another population in Nebraska, the smallest gravid female had a carapace length of 175 mm but was older than 14 years, whereas the youngest gravid individuals based on annuli were 11 years old with carapace lengths of 187 and 207 mm (Ruane et al. 2008). Juveniles also were verified by presence of recent plastral scute growth, indicated by wide growth annuli and a light area along the midline of the plastron (Congdon and Keinath 2006). Adults were determined by cessation of wide growth annuli and, if visible, presence of >12 growth annuli. Adult males were distinguished by concave plastrons and anal vents that exceeded the length of

the carapace (Congdon et al. 2008; Ernst and Lovich 2009). Females were distinguished by the absence of male features, including flat plastrons and anal vents within the length of the carapace (Graham and Doyle 1977; Hamernick 2000; Ernst and Lovich 2009). The inguinal region of adult females (abdomen near back legs) was palpated to determine whether adult females were gravid (Hamernick 2000; Ruane et al. 2008; Hasler et al. 2015).

Four photos were taken of every turtle: carapace, plastron, and head views, as well as annuli with a metal ruler placed beneath the pectoral scutes. All Blanding's Turtles were marked with a unique ID code at time of capture by making systematic notches along the marginal scutes of the turtle's carapace with a rotary Dremel® tool (Hamernick 2000).

Radio transmitters

We began placing radio transmitters (model RI-2B; Holohil Systems Ltd., Ontario, Canada) on adult Blanding's Turtles on 8 June 2019. Transmitter placement was restricted to individuals ≥ 750 g to ensure weight of devices adhered to turtles was no more than 5% of total body weight. We continued radio transmitter placement on *E. blandingii* in summer 2019 and throughout the 2020 field season when individuals met or exceeded 750 g body weight.

To attach a radio transmitter to a turtle, the magnet was removed to initiate the transmitter, and the frequency was tested using a receiver. The best frequency of the transmitter was determined by manipulation of the receiver dial. If the best frequency was

different from the frequency programmed by Holohil, this frequency was noted on the Turtle Data Sheet. The turtle was placed on a balanced surface (e.g., upside-down yogurt or Plasti Dip® container) to allow the turtle's limbs to move freely without disturbing transmitter attachment. A rear carapace scute was selected for transmitter placement. This area was scrubbed with the abrasive side of a sponge to move natural debris (e.g., algae). The scute also was wiped clean with a paper towel or cotton swab soaked with 91% isopropyl alcohol. The treated scute was allowed to dry. A quarter to dollar coin-sized amount of Devcon® 5-minute Epoxy was placed onto a disposable surface (e.g., piece of cardboard), and the epoxy was mixed thoroughly with a toothpick. Using the tool provided on the epoxy container, the epoxy was applied to the center of the clean scute. We avoided applying epoxy to scute margins to ensure proper annuli growth. The transmitter was applied to the epoxy immediately, and a small amount of tape was placed on the transmitter and scute to secure the device as the epoxy cured. The tape was removed after 8-10 minutes, and epoxy was cured for 1 hour prior to release of the turtle at the point of capture.

Temperature loggers

We attached temperature loggers (model DS1921G-F5# Thermochron, 4K; iButtonLink LLC, Whitewater, Wisconsin) to 12 adult Blanding's Turtles. Each iButton was programmed through the OneWireViewer software program to record temperature every 3 hr prior to attaching temperature logger to turtle. To waterproof temperature loggers, we coated devices with Plasti Dip® (Roznik and Alford 2012; Milanovich et al. 2017). We tied thread or waxed dental floss around iButtons and lowered devices directly

into the Plasti Dip® container. Waxed dental floss was ideal because it did not easily slip off devices. We allowed the first coating of Plasti Dip® to dry for 30 minutes prior to adding a second coat. Upon application of second coats, devices dried for at least 4 hours prior to attachment. These steps were completed prior to turtle capture. Preparation of the selected carapace scute was conducted in the same manner as transmitter attachment. A rear carapace scute was selected for iButton placement, and this area was scrubbed with the abrasive side of a sponge to remove debris (e.g., algae). The scute was then wiped clean with 91% isopropyl alcohol using a paper towel or cotton swab. The treated area was allowed to dry prior to placement of epoxy; epoxy was prepared and applied as described above. iButtons were adhered to epoxy immediately, and a small piece of tape was placed on iButtons and scute to secure devices as the epoxy set. Tape was removed after 8-10 minutes, and the epoxy cured for at least 1 hour prior to release of the turtle at the point of capture.

Radio telemetry tracking

We obtained locations of turtles using hand-held receivers (models R-1000 and RX-6000; Communications Specialists, Inc., Orange, California) and 3- or 5-element Yagi antennas. From June to September 2019, we located turtles approximately every 1 to 22 days while in the field; we located turtles more frequently (1 to 7 days) during the active period of May to September in 2020. We also tracked locations of overwintering turtles a few days both years, with additional telemetry locations recorded once in October, November, January, and March of the first year and October, December, and

January of the second year. All radio transmitters were removed on 24 and 25 May 2021, and these final locations also were included in radio telemetry analyses.

Some attempts to locate turtles were unsuccessful due to transmitter failure, signal interference, and inaccessibility to turtles or wetland sites. We focused spatial analysis on turtles that we could track to exact or close locations. Exact locations were determined by "zero-gain tracking" (e.g., Hasler et al. 2015). We used minimum gain to locate the signal and exact location of the turtle on foot, i.e., we had a visual on the turtle. Unless recapture was necessary, radio tagged turtles were undisturbed. For other locations, we first tried to locate the turtle using zero-gain tracking but were impeded by water depth or other constraints. If minimum gain was used at these locations and the turtle was within 10 m of the observer, the observation was recorded as a close location.

Thirteen of fourteen turtles outfitted with radio transmitters were included in space use analysis. One adult male was excluded because only two radiotelemetry locations and mortality were recorded for the individual. We included initial captures, trap recaptures, exact and close locations, and long-distance sojourns in our space use analysis. Radiotelemetry locations were input as point features into ArcGIS 10.8.1 (Environmental Systems Research Institute, Redlands, CA, USA) using a 2018 Cherry County, Nebraska digital orthophoto quadrangle (DOQ; USDA, 6-m resolution) from the Natural Resources Conservation Service as a base layer. Point features initially were imported using the WGS84 coordinate system (same as datum of GPS) and later exported as UTM Zone 14N to preserve distance calculations and for consistency with other data layers. To calculate home range size, the minimum convex polygon (MCP) method was

used. This method has been used estimate home range size of Blanding's Turtles (Piepgras and Lang 2000, Innes et al. 2008, Schuler and Thiel 2008). One of the limitations of using MCPs to estimate home range size is that it can overestimate the range (Gregory 2017). Generated by the minimum bounding geometry tool, a convex polygon was constructed that included all locations for each individual turtle. We selected convex hull as the geometry type parameter to output the smallest convex polygon. Convex hull is more compact than the default rectangle by area parameter. The ArcGIS measurement tool was used to calculate mean range length, the largest distance between two observed radiotelemetry locations, for each turtle.

Results

Overall trapping effort and capture success

A total of 280 turtles (including recaptures) of 5 species were captured from 15 May 2019 to 25 September 2020, representing Northern Painted Turtles (65% of all captures), Blanding's Turtles (16%), Common Snapping Turtles (*Chelydra serpentina*; 13%), Ornate Box Turtles (*Terrepene ornata*; 5%), and Yellow Mud Turtles (*Kinosternon flavescens*; 1%) (Table 1). Some turtles were captured opportunistically by hand (11%), but most were captured in traps (89%) (Table 1). Most hand captures for other species (Ornate Box Turtles and Painted Turtles) took place at the beginning of the first field season for the purpose of practicing turtle measurements. We focused our efforts on capturing Blanding's Turtles but could have captured higher numbers of other species by hand. Trapping effort was similar in 2019 and 2020, with exception of

trapping continuing into September in 2019 (Table 2). Overall trap success was 7.9 turtles per 100 trap nights across all species and 1.1 individuals per 100 trap nights for Blanding's Turtles. Total numbers of Northern Painted, Blanding's, and Common Snapping turtles captured in traps were similar between years (Table 3). Trap type influenced capture success, with hoop traps yielding the most captures, after adjusting for trap effort (Table 4). Most turtles were captured in June, July, and August both years (Fig. 1). Blanding's, Snapping, and Painted turtles were captured from five pastures (Fig. 2), which were in areas with the greatest trapping effort (at least 230 trap days each; Table 5).

Other organisms captured in traps during the study included the following: 22 Northern Leopard Frogs (*Lithobates pipiens*), 20 giant water bugs (*Belostoamtidae*), 10 tadpoles, 11 gartersnakes (*Thamnophis radix* and *T. sirtalis*), 2 adult dragonfly, 2 dragonfly larvae, 2 Pied-billed Grebes (*Podilymbus podiceps*), 1 unknown insect larva, 1 fledgling Red-winged Blackbird (*Agelaius phoeniceus*), 1 American Bullfrog (*Lithobates catesbeianus*), 1 Northern Pike (*Esox lucius*), and 1 small fish of unknown species. We also observed damage to some traps by other animals (possibly racoons or muskrats) (Fig. 3), as well as abundant snail biomass around and in traps (Fig. 4).

Blanding's Turtle captures, measurements, and observations

Over the two years, a total of 33 unique Blanding's Turtles were captured, marked, measured, and released from 27 May 2019 to 25 September 2020 (Table 6). This included 18 juveniles (54%), 8 adult females (24%), and 7 adult males (21%). At initial

time of capture, 25 Blanding's Turtles (76%) were caught by trap, and 8 (24%) were captured by hand. We had 3 occurrences of hand captures on dry roadways (gravel and paved) and 1 in each the following locations: flooded roadway, two tracks in grassland pasture, edge of wetland trench, wetland surface, and dry wetland (in dry vegetation). Most Blanding's Turtles were captured in Homestead (45%), followed by West Holding (18%), and East Holding (12%) pastures. However, Homestead had much higher trap effort compared to East Holding and West Holding, and area of water bodies was smaller in Homestead (Table 5). When adjusted for trap effort, West Holding had greater trap success for Blanding's Turtles than Homestead and East Holding (Fig. 2). Pastures where Blanding's Turtles were not detected had less than 230 trap days. Of note, Blanding's Turtles were never detected in Mail Route pasture, only 0.67 km from Hill Pond and located on the western edge of the ranch, which was a site with abundant Painted Turtles (Fig. 2).

Body size measurements were relatively similar between male and female Blanding's Turtles (Table 7). There were no significant differences in mean weight, carapace length, carapace width, shell height, or plastron length between adult males and females. Males had larger mean plastron widths than females (Table 7; $P = 0.009$). The smallest Blanding's Turtle captured was 140 g, whereas the largest was an adult male at 1850 g. Juvenile Blanding's Turtles < 800 g were captured most frequently (Fig. 5). Weights of all individuals, regardless of age or sex, were highly correlated with carapace lengths (Fig. 6). Counts of annuli, a rough estimate age, ranged from 3 to 20+, with juveniles < 13 (Table 6). Overall, trap type influenced the size (weight) of turtle captured

(ANOVA $F = 3.6$, P = 0.038, df = 2), with larger Blanding's Turtles captured in hoop traps compared to crab traps (Fig. 7).

We handled nearly half of the Blanding's Turtles (16 individuals) at least once after initial capture, with some tracked with radio telemetry or recaptured in traps, and one opportunistically recaptured by hand (Table 8). We observed the following with regard to type of trap in which Blanding's Turtles were captured/recaptured: #5 (a juvenile) was captured first in a small crab and twice again in hoop traps; #10, #11, and #12 (all adults) were captured only in hoop traps; #22 (a juvenile) was first captured in large crab and then in hoop trap; and #26 (an adult) was captured first in a large crab and twice again in hoop traps. Nine adult turtles were measured in both field seasons. The average increase in weight was 95 g (26.4 SE) and average increase in carapace length was 0.1 mm (0.14 SE).

Blanding's Turtles escaped from both modified and unmodified traps in 2020 (Table 9). The 2 turtles that escaped unmodified traps did so within a 17-hr period. Only in one instance did the presence of an adult female (#26) in a modified hoop trap appear to attract and catch an adult male (#12) on 24 July 2020. We lacked enough data, and our results were too variable, to make conclusive inferences about effectivity of trap modifications.

In our 2020 field season we observed individual Blanding's Turtles on land or resting in terrestrial habitats. Individuals were inconspicuous and otherwise undetectable without radio telemetry. In general, turtles made no movement when approached by

researchers. One individual, a juvenile (#27), moved to water upon observation. On 2 June 2020 (1700 h), an adult female (#8) was observed in upland grasslands in Homestead Pasture. We recorded this behavior for this individual again on 26 June 2020 (1525 h) in lowland grassland near the shoreline of a small pond in Homestead Pasture (Fig. 8). On 18 June 2020 (1130 h), individual #21, a juvenile of unknown sex, was discovered on land within vegetation and captured opportunistically by hand in upland and lowland wet meadow habitat in Homestead Pasture. We observed an adult female (#11) in the same location in lowland grasslands within vegetation near 4 Morgan and Morgan Lake in West Holding Pasture on 17 and 19 July 2020 (1216 and 1647 h, respectively; Fig. 9). On 5 August 2020 (1006 h), an adult female (# 15) was observed in upland grasslands within vegetation in Homestead Pasture. This behavior was recorded for this individual again on 8 August 2020 (1244 h) in lowland grasslands near the shoreline of a small pond in Homestead Pasture. We observed #15 a third time on 11 August 2020 (1118 h) in lowland grasslands within vegetation near the shoreline of a large wetland in Homestead Pasture. On 8 August 2020 (1211 h), a juvenile (#27), that was on the larger end of the juvenile size range at 770 g, was found in lowland grasslands within vegetation near the shoreline of a large wetland in Homestead Pasture. We observed three adult females (#8, #15, and #26) in lowland grasses within vegetation near C Lake and Clifford Creek wetland sites in Homestead Pasture on 24 May 2020 (1412, 1515 and 1610 h).

Temperature data loggers installed in the 2019 field season were successfully recovered from two adult female Blanding's Turtles in June 2020. Three data loggers

installed in the 2020 field season were recovered in May 2020 from two adult females and one adult male. External carapace temperature data was recorded from 15 August 2019 to 28 April 2020 and 19 July 2020 to 31 March 2021. External temperatures decreased in late September and early October and began increasing in late February and early March (Fig. 10).

Blanding's turtle space use

A total of 14 individual Blanding's Turtles including 13 adults (7 females, 6 males) and 1 juvenile were outfitted with transmitters during the study following initial capture. The presumed juvenile (770 g) was measured on the upper end of juvenile body size and exceeded body mass requirements of transmitter placement by 20 g. We tracked 10 individuals (6 females and 4 males) and had two transmitter failures (#4 and #11) in 2019, and 13 individuals (6 females, 6 males, and 1 juvenile) were tracked in 2020. We recorded one mortality (#24) and one transmitter failure (#12) in 2020. One transmitter failure (#11) was recorded in 2021. Blanding's Turtles #12 (adult male) and #11 (adult female) both were recaptured in traps following gaps in telemetry points (55 and 332 days, respectively). Locations were recorded over two field seasons for a total of 9 adults (5 females and 4 males). Five individuals were tracked in only one field season: 1 in 2019 and 4 in 2020. The single year of telemetry data recorded in 2019 was due to transmitter failure (#4), and the four individuals in 2020 were initial captures.

From 8 June 2019 to 25 May 2021, we recorded a total of 290 locations of Blanding's Turtles with radio transmitters. Of the 290 radio telemetry locations, 272 were

exact locations with detailed habitat descriptions. The other 18 locations included 14 close locations and 4 radio transmitter failures. Blanding's Turtles were most often observed in water (95%; 258/272). Observations of Blanding's Turtles on land were infrequent (5%; 14/272). One third (5/14; 36%) of land observations were conspicuous and, of those, 80% (4/5 observations) were initial captures by hand in 2019 (a wet year). The single observation (1/5) that was conspicuous, but not a hand capture, represented the location of Blanding's Turtle #15 (adult female) in grassland near a small wetland on 18 June 2020 (10:22 h). The remaining 64% (9/14) of Blanding's observations on land were inconspicuous and occurred in the summer months (late May to August; see section on land behaviors). When Blanding's Turtles were located in water, 94% (242/258) were observed underwater, 3% (8/258) were floating, and 3% were basking (7/258). Most (251/272) radio telemetry locations had descriptive vegetation notes, with 68% (171/251) having emergent, 75% (187/251) having submerged, and 46% (116/251) having floating vegetation. For 36% (90/251) of these underwater observations, sites had all three vegetation types.

Movements between wetlands

Females made the farthest overland movements between wetland sites both years, with most males remaining in a single wetland. The largest recorded movement was recorded on 28 June 2019. An adult female (#2) traveled 1,603 m west of Morgan Lake (cattail marsh) wetland in West Holding pasture to Corral Lake in East Holding pasture. Both years, #2 used two wetland sites: Corral Lake and Morgan Lake. Corral Lake was used by #2 in summer, fall, and winter months, and Morgan Lake wetland was used only

in the spring. A ditch connected these two wetlands. From 30 May 2020 to 2 June 2020, #8 (adult female) traveled 346 m from a drying, temporary wetland to an upland sand dune and grassland habitat. The individual was discovered concealed in dried vegetation on 2 June 2020 (1700 h). On 4 June 2020, #8 had moved 498 m from an upland grassland site to a small, but deep (e.g., over hip) wetland near Clifford Creek. Over the 5-day period (30 May 2020 to 4 June 2020) and 3 separate recorded telemetry locations, the adult female moved an estimated total of 844 m between the two wetland sites. Prior to the female's return to resident wetland C Lake in July, #8 was on land within vegetation near the Clifford Creek wetland site on 26 June 2020 (Fig. 8). On 24 May 2021, #26 (adult female) was found concealed in grassland habitat near the Clifford Creek wetland site. The female had traveled 1,145 m from overwintering site. Those were the two largest recorded movements in Homestead Pasture wetland complex for both years. A male (#12) traveled 295 m between two wetlands in Homestead Pasture on 16 August 2019, and this observation represented the largest recorded movement in males in our study. Two individuals, one from each summer wetland habitat, did not make any recorded movements between wetlands. One male (#10) moved throughout C Lake, and one female (#20) remained in the north to northeast corner of Corral Lake for the duration of the study.

Overwintering

Overwintering locations were recorded for 12 turtles in October, November, January, and March of the first field season and October, December, and January of the second field season (see Appendix A for examples of overwintering wetland sites). We

recorded a total of 50 overwintering locations at 3 different wetland sites. We were able to compare overwintering movements between field seasons for 8 adults. Blanding's Turtles moved a range of 1.4 m (juvenile) to 166.6 m (adult male) from 31 October 2020 to 18 January 2021 (Table 10). Mean movement in winter months was 37.9 m (± 52.6 SD). Overwintering individuals were grouped in one wetland in the second field season. Five individuals (2 males, 2 females, and 1 juvenile) were within a 9.6 m^2 area in Little C Pond on 18 January 2021. Only one adult female (#15) overwintered in Little C Pond both years. Two adult males (#10 and #28) were 7.8 m apart on 11 December 2020 and 5.9 m on 18 January 2020. On 31 October 2020, #10 was within 3.7 m of #27 (juvenile).

Home ranges

Blanding's Turtles occupied from one to four wetland sites, and individual space use ranged from 1.4 to 62.6 hectares (mean, 18.1 ha) (males mean, 9.12 ± 5.5 ha SD; min-max, 3.5-17.8 ha). Adult females represented the largest home range sizes (mean, 26.8 ± 21.8 ha; min-max, 3.7-62.6 ha). Turtle #4 had the largest home range at 62.5 ha (Fig. 11; Table 11). This individual was radio-tracked only in the 2019 field season and had a total 22 radio telemetry records. Turtle #2 had the second largest home range at 47.4 ha. This female was radio-tracked both field seasons and had 25 total records. Turtle #11 also was radio-tracked both field seasons but only had 10 total records. This individual had the third largest home range at 29.1 ha. Of note, the home ranges of these three females intersected near 4 Morgan wetland in West Holding pasture (Fig. 11). Adult females #8 and #26 had the largest home ranges in the Homestead Pasture wetland complex. Turtle #8 had the fourth largest home range at 26.5 ha. This female was radio-

tracked both field seasons and had 40 total records. Turtle #26 had the sixth largest home range at 12.2 ha. This individual was radio-tracked only in the 2020 field season and had 10 total records. As previously described, turtles #26 and #8 had similar movements between wetlands (Fig. 12). Mean home range sizes were not significantly different between males (9.1 ha) and females (26.8 ha) ($p=0.08$). Turtle #17 had the largest home range size of adult males at 17.8 ha. This male resided in Corral Lake wetland in East Holding pasture for the duration of the study. Turtle #17 was radio-tracked both field seasons and had a total 22 radio telemetry records. Turtle #12 had the second largest home range size of adult males at 10.6 ha. This individual represented the largest male home range size in the Homestead Pasture wetland complex. Turtle #12 represented the highest number (3) of wetlands used by males and had the largest movement of males (295 m) overall. This male was radio-tracked both field seasons and had a total 26 radio telemetry records. Individual observed home range length, the farthest distance between two points (Pluto and Bellis 1988), ranged from 209 to 2,555 meters (mean, 1,023 m). Mean home range length of females (1,427 m) was significantly different from males (622 m) ($p=0.05$).

Adult females used more and different wetlands than males. The maximum number of known wetlands used by individual turtles was up to 4 sites (#4 and #8). Wetland sites used by females ranged from 1 to 4 (mean, 2.9 ± 1.1 SD), and males ranged from 1 to 3 (mean, 1.8 ± 0.8 SD). Turtle #4 used 4 wetland sites in 4 different pastures, while #8 used 4 wetland sites within 1 pasture. Both individuals were female. One adult male (#12) was recorded using 3 wetland sites. In general, males used fewer wetland sites

and were generally recorded at one to two wetland sites. A juvenile (#27) was recorded at one wetland site, but this individual was captured late in the second field season.

Discussion

In lakes and ponds on a private ranch in the western Sandhills, relative abundance of Blanding's Turtles was second to Painted Turtles. These data appear to be the first relative abundances of Blanding's Turtles and other species reported for a turtle community in Nebraska. Although the largest population of Blanding's Turtles throughout its range-wide distribution resides in the Sandhills of Nebraska (Lang 2004), it is not surprising that Painted Turtles were the most abundant turtle at our site. Our results were consistent with that of small wetland complexes in Wisconsin (Ross 1989) and Ontario (Browne and Hecnar 2007). The most abundant turtle species at suitable wetland sites commonly is the Painted Turtle (Ernst and Lovich 2009). Diet, habitat, and basking habits of Painted Turtles are highly generalized (Ernst and Lovich 2009), likely contributing to their larger numbers. Competition for resources such as basking structures or food can restrict numbers of one or more species (Ross 1989). Studying these proportions may serve as an evidence of species declines. In Ontario, recent surveys ranked relative abundance of Blanding's Turtles fourth to Painted Turtles, a decline from third in the 1970s (Browne and Hecnar 2007). Snapping Turtles ranked second and Northern Map Turtles (*Graptemys geographica*) third in the Ontario population (Browne and Hecnar 2007). Blanding's Turtles at wildlife areas in northwest Indiana were considered "very common" in the 1930s. Surveys in the 1990s captured only four individual Blanding's Turtles at two sites, while Painted Turtle numbers had increased

from rare to one of the most common (Brodman et al. 2002). At our study site, food resources did not appear to be limited, as snails are a common dietary item (Ernst and Lovich 2009; see Fig. 4). Although thermoregulatory resources (e.g., muskrat structures) were reduced by severe weather in the 2019 field season, we observed Blanding's Turtles and Painted Turtles basking at the water's surface, along wetland edges, and on top of traps.

We captured Blanding's Turtles in baited traps from late May to August, with peaks in trapping success in June 2019 and July 2020 (Fig. 1). Trapping success was lowest in May and September. No Blanding's Turtles were captured in September 2019. Only an adult female (Turtle #1) was captured on 25 May 2019. No traps were set in September 2020. Low trapping success in May and September likely was due to low temperatures. Like other reptiles, turtles are ectotherms, and lower water temperatures would tend to reduce activities such as feeding. Water temperatures in May at our study site ranged from 10.5-24.4 °C. In Illinois and Missouri, Blanding's Turtles did not enter baited traps until water temperatures reached 18 °C (Kofron and Shreiber 1985, Rowe and Moll 1991), and our water temperatures in May were mostly lower, as our study site is at the highest elevation for this species throughout its distribution. By mid-September, water temperatures at our study site again measured < 18 °C. In fact, in September and October Blanding's Turtles entered overwintering sites. Our 2019 timing of greatest trap captures (June and July) was consistent with other studies (Kofron and Schreiber 1985; Rowe and Moll 1991). In Illinois, peaks in trap captures of Blanding's Turtles were recorded in June and August, with few turtles (n=6) captured in late May and none

captured in September (Rowe and Moll 1991). Kofron and Shreiber (1985) also detected a seasonal trapping pattern of early and late summer peaks with a lull in July for Blanding's Turtles in Missouri. Our study differed between years. We observed a slight lull in trapping success in July of 2019, but a peak in 2020 (Fig. 1). Lower trapping success in July could be explained by feeding behavior. In Missouri, Blanding's Turtle stopped feeding in mid-July and resumed once water temperatures dropped to 21°C (Kofron and Shreiber 1985). We suggest timing of trapping efforts be focused on June through August in western Nebraska to document *E. blandingii* in western Cherry County, with over 200 trap nights needed (Table 2).

Hoop traps captured the most turtles of all species (Table 4), and largest Blanding's Turtles (Fig. 7). We captured 7 times as many Blanding's Turtles in hoop traps compared to large crab traps. Our trapping effort consisted mostly of large crab traps (60%). Hoop traps may have been biased in favor of capturing larger turtles. In some cases, hoop traps were placed adjacent to muskrat structures where large, basking turtles had been observed previously. To keep trap entrances underwater, hoop traps were placed in deeper, often more open, water. This also likely attributed to captures of larger turtles due to differences between habitats used by adults and juveniles (Congdon et al. 2000). Shallower areas of wetlands tend to be used by juveniles (Congdon et al. 2000). Net dimensions of hoop and large crab traps were wide enough to allow smaller turtles to escape. We observed these kinds of escapes with Painted Turtles. To capture more juveniles, future studies could focus hoop trap placement on wetland edges. Other trapping methods, such as dip-nets, have also been used to capture juvenile freshwater

turtles (Tesche and Hodges 2015). Differences in habitat use between adults and juveniles is not well documented. Hoop net diameter has been shown to influence the number and size distribution of captures of Painted Turtle and Snapping Turtle (Gulette et al. 2019). For both species, smaller hoop nets had higher capture success with smaller turtles, and larger hoop nets were more efficient at capturing larger individuals (Gulette et al. 2019). When capture success of loose and narrower hoop-trap entrances was compared, loose-mouth trap openings dramatically increased capture success of six freshwater turtle species in Texas (Mali et al. 2014). Researchers suggested that narrow-mouth trap openings be intentionally loosened to increase trap success (Mali et al. 2014). We purposefully loosened crab trap entrances, to ensure turtles had enough space to enter, but not those of hoop traps used in our study. To avoid escape and better assess the turtle community, smaller mesh sizes and a range of hoop trap diameters should be used for monitoring of freshwater turtle species (Gulette et al. 2019). We recommend use of hoop traps if one trap type is used at study sites in Nebraska.

Blanding's Turtles in this study did not demonstrate sexual size dimorphism. Fawn Lake Ranch's *E. blandingii* population is suggested to be monomorphic like neighboring populations in Grant County (Ruane et al. 2008) and Valentine National Wildlife Refuge (VNWR; Rowe 1992). Only mean plastron width differed between males and females in our study ($P = 0.009$); however, this measurement is not commonly reported in the literature. Lengths of the carapace (CL) and plastron (PL) are reported more often. At VNWR, females had longer plastrons than males, and higher shells, but CL was not significantly different (Rowe 1992). Germano (2000) did not detect

differences in plastral lengths, but mean mass and CL between sexes differed, with males larger than females. Our body size measurements fell within the ranges of other demographic studies throughout the species distribution (Congdon et al. 2008). Mean turtle mass and carapace lengths for both sexes were slightly larger than other populations in western Nebraska (Germano 2000; Ruane et al. 2008), Massachusetts (Graham and Doyle 1977), Michigan (Pappas et al. 2000), and females in Michigan (MacCulloch and Weller 1988). Turtle mass was highly correlated with CL at Fawn Lake Ranch and VNWR (Fig. 6), which has been noted previously in another study (Germano 2000). In Massachusetts, weight and length also were highly correlated (Graham and Doyle 1977). Size dimorphism in this species has been considered questionable (Pappas 2000). The shell shapes of male and female *E. blandingii* are morphologically different, with males having slightly concave plastrons. Plastral concavity in males, indeterminate shell growth, and small sample size may all attribute to differences in body size between sexes. Adults may reach maturity at smaller sizes in other regions (Graham and Doyle 1977). We suggest this could be explained by differences in available dietary resources and latitudinal geographic variation. As previously described, Blanding's Turtles at Fawn Lake Ranch did not appear to be limited by food resources.

At Fawn Lake Ranch, Blanding's Turtles selected overwintering locations by late September. Water temperatures ranged from 9.4-16.1 °C the first field season (27 September 2019) and 18.9-25.0 °C the second field season (25 September 2020). Timing and conditions (e.g., water temperatures) at which Blanding's Turtles moved to overwintering locations vary throughout the species range. In other parts of their range,

Blanding's Turtles moved to overwintering sites between September and late November when water temperatures reached 5-13 °C (Kofron and Shreiber 1985, Ross and Anderson 1990, Rowe and Moll 1991, Newton and Herman 2016). Turtles in our study overwintered within or near summer wetland habitats. During the inactive season, Blanding's Turtles were not entirely dormant at our study site, which has been reported in other areas of its distribution (Kofron and Shreiber 1985, Ernst and Lovich 2009, Newton and Herman 2016). We recorded turtle movements in ice-covered wetlands from our October to January radio telemetry surveys. Overwintering wetlands did not freeze completely, allowing Blanding's Turtles to move under the ice. In the second field season, an ice auger was used at three of four overwintering wetland sites to confirm open water under ice in overwintering wetlands. Most individual Blanding's Turtles selected hibernacula in shallower water (5/8; 62%), while some chose deeper portions of wetlands (3/8; 38%). These individual depth selections may have been preferential, as they frequently coincided with depths observed during the active season. This variability in overwintering habitat, as well as individual movement and timing were consistent with other studies (Kofron and Shreiber 1985, Ross and Anderson 1990, Newton and Herman 2016). Blanding's Turtles also were observed hibernating communally (up to 5 individuals) at Fawn Lake Ranch. Communal overwintering has been reported in other populations throughout its range (Ross and Anderson 1990, Newton and Herman 2016), but this is the first report of this behavior for Blanding's Turtles in Nebraska. A group of thirteen individuals was reported overwintering communally in a population in Nova Scotia (Newton and Herman 2016). Reproductive factors may be a driving factor to

communal overwintering in turtles. In a Nova Scotia population of Blanding's Turtles, copulation behaviors were observed in September through January (Newton and Herman 2016). Other factors such as philopatry or site fidelity may also contribute to communal overwintering in Blanding's Turtles (Newton and Herman 2016).

At Fawn Lake Ranch, individual Blanding's Turtles used wetland complexes in a variety of ways at different sites. Some turtles used the same wetland for the duration of the study, while others moved among wetlands. This was consistent with patterns of habitat use in other parts of their range. Blanding's Turtles typically display two different types of movement—annual home range movements and long-distance movements (Ross and Anderson 1990, Rowe and Moll 1991, Rubin et al. 2001). Annual home range movements include regular travel within summer wetlands, between wetland habitats, and females to nesting sites. Long-distance movements, sometimes referred to as sojourns, occur on a less-than-annual basis, with turtles returning to previously inhabited wetlands (Rowe and Moll 1991). Seasonal movements are associated with suitable habitat selection and reproduction strategies. In our study, females had the largest home range sizes and utilized more wetland sites throughout the active season. Only female Blanding's Turtles displayed long-distance movements exceeding 1,000 m. These migrations coincided with nesting seasons of Blanding's Turtle populations in the state (Rowe 1992, Ruane et al. 2008, Lang 2004). Female nesting behaviors were not observed in our study. In general, males remained in summer wetland habitats year-round.

Home range length, the greatest distance between any two recorded locations (Pluto and Bellis 1988), differed between males (mean, 622.2 m ± 390) and females

(mean, 1,426.9 m ± 828.6). This finding was unique to our study. Home range length did not differ between the sexes in other studies (Ross and Anderson 1990, Rowe and Moll 1991, Piepgras and Lang 2000, Innes et al. 2008, Schuler and Thiel 2008). Mean home range size, a measurement of habitat area that included all radio telemetry points, did not differ significantly between males (mean, 9.1 ha ± 5.5) and females (mean, 26.8 ha ± 21.8). Mean home range size in our study was larger than populations in Illinois (Rowe and Moll 1991), Minnesota (Piepgras and Lang 2000), New Hampshire (Innes et al. 2008), and Wisconsin (Ross and Anderson 1990). In other studies, home range size also did not differ between the sexes (Ross and Anderson 1990, Rowe and Moll 1991, Piepgras and Lang 2000, Innes et al. 2008, Schuler and Thiel 2008). Mean home range size of Blanding's Turtles varied from 0.6 ha in Wisconsin (Ross and Anderson 1990) to 63.0 ha in Minnesota (Piepgras and Lang 2000). In our study, the largest movements were terrestrial, occurred in May and June, and were made by females only. Although we did not detect gravidity or nesting behaviors in our study, greater distances traveled by females may be attributed to nesting behaviors (Piepgras and Lang 2000). In Ontario, gravid females had significantly larger home range sizes than nongravid females and males (Millar and Blouin-Demers 2011). Aside from differences in methodologies between studies, the large variation of home range sizes throughout this species distribution could be attributed to turtle age, size, sex, population densities, and/or locality features such as climatic conditions and availability of resources and habitat (Piepgras and Lang 2000, Innes et al. 2008). Space use of Blanding's Turtles does not appear to be limited at Fawn Lake Ranch. Larger home range sizes observed at our study

site are likely attributable to the seemingly unlimited access to suitable wetland and upland habitats in a generally unaltered landscape. Numerous wetlands surrounded by upland sand dunes is also present at neighboring Valentine National Wildlife Refuge, where the largest population of Blanding's Turtles is currently known. As a long-lived species, one to two-year studies are likely not indicating the full space use of Blanding's Turtles (Schuler and Thiel 2008). We assume turtles at Fawn Lake Ranch use a greater spatial area than what was described here. The full scope of terrestrial and aquatic habitats should be considered in making effective habitat management decisions for this species. Movement corridors, such as the intersection of three adult females in this study, also should be considered.

We observed turtles on land within grassland vegetation on 10 occasions. These observations were associated with four individual females and one large juvenile that possibly was a reproductively active adult female. Apart from one observation, all other observations were along wetland edges, within 5-17 steps of water, with turtles completely burrowed underneath thick tufts of grassland vegetation. Turtles were not buried in the substrate. At time of observation, turtles were not visible to observers from top-down views and were otherwise undetectable without radio telemetry. Except for the large juvenile (#27), turtles did not make any movements when approached by observers. The juvenile moved to water when located. In early June 2020, one female (#8) was observed in upland habitat under dense vegetation. This observation likely was associated with nesting activities. Our observations may have been associated with aestivation, known as a period of inactivity or dormancy in hot and/or dry conditions. We cannot

directly tie our observations of turtles to this state, because we lack the data to support metabolic states of turtles. Apart from one observation, we also did not record turtles in the same location for consecutive days. One adult female (#11) was recorded in the same grassland location for two days (17 July and 19 July). If this was the case, terrestrial aestivation in Blanding's Turtles has been attributed to habitat displacement such as drying of residential wetlands and unsuitable water temperatures (Rowe and Moll 1991, Ernst and Lovich 2009). In June 2020, we observed a large juvenile within a tuft of grasses in a drying wetland. Our land observations of female Blanding's Turtles might be best explained by unsuitable water temperatures in May and September. At the time observations were recorded in late May 2021, ambient temperatures (23.9 °C) were warmer than water temperatures (21.1 °C). In September 2020, ambient temperatures (28.3–25.0 °C) again were warmer than water temperatures (21.7–22.2 °C). We noted that external shell temperature was warm to the touch in these individuals. Blanding's Turtles may have been using ambient temperatures to thermoregulate when water temperatures were cooler than air temperatures (Rowe and Moll 1991). Water temperatures were essentially equal or exceeded that of ambient temperatures in June 2020. As noted previously, on land observations recorded in June 2020 were more likely associated with nesting activities. Similar behaviors on land were reported between June and September in central Wisconsin and northeastern Illinois (Ross and Anderson 1990, Rowe and Moll 1991). At time of recorded behaviors in Illinois (Rowe and Moll 1991), water temperatures ranged from 14-21°C, while water temperatures in Wisconsin ranged

from 18-28.5° (Ross and Anderson 1990). Specific features of aestivation activities generally are not understood.

Management

Like other turtles, Blanding's Turtles are threatened by road mortality. Blanding's Turtles utilize multiple habitats per year to thermoregulate, breed, nest, feed, and hibernate, and these overland movements may involve crossing roads. All ages and sexes of turtles, including emergent hatchlings, are impacted by road mortality in different ways (Kofron and Shreiber 1985, Standing et al. 1999; Beaudry et al. 2010b). No evidence of road mortality of Blanding's Turtles was observed at Fawn Lake Ranch. We observed road mortalities in several Ornate Box Turtles and one Yellow Mud Turtle. There only was one main, county road that is not used except by ranch personnel, mail carriers, and nearby neighbors. This road was both near and crossed through wetland habitats where Blanding's Turtles were captured. We should note two female Blanding's Turtles were captured within and along the road near the same wetland habitat in June 2019. The timing of these encounters coincided with the nesting season. Due to overland movements associated with nesting behaviors, females may be more vulnerable to road mortality (Steen et al. 2006). Females also have been observed utilizing roadsides as nesting sites (Beaudry et al. 2010a). We observed this behavior numerous times in Painted Turtles at our study site. In Maine, peaks in road mortality for female Blanding's Turtles coincided with the nesting season (June to early July; Beaudry et al. 2010b). Both female and male Blanding's Turtles experienced peaks in road mortality in September, which was likely associated with movements to hibernation locations (Beaudry et al.

2010b). It should be noted that more extensive roadway systems and a larger human population influenced road mortality rates in Maine (Beaudry et al. 2010b). At VNWR, a site with many roads adjacent to and crossing through wetland habitats, road mortality was related to increases in human recreational activity (on weekends) and was location-specific (Lang 2004). Turtle road mortality in general varies over space and time and studying movements can help identify threats to declining species like Blanding's Turtles (Beaudry et al. 2010b). Simple efforts such as installation of fencing in combination with culverts and signage have been implemented at VNWR to reduce the risk of road mortality and increase awareness of turtle crossings (Lang 2004). Due to the low traffic volume/absence of roadways at Fawn Lake Ranch, these efforts do not appear to be necessary currently. We suggest that caution be taken (e.g., reduced speed) where the road meets wetland sites to avoid turtle-vehicle collisions. Turtle crossing signage at these locations also could be implemented. The timing of these efforts could be focused on spring through late summer when turtles are active.

Stable turtle populations require high landscape connectivity and high adult survivorship, and these characteristics offset intrinsic threats of delayed sexual maturity, low annual fecundity, and low recruitment rates (Ernst and Lovich 2009). We would consider Fawn Lake Ranch to be sufficient in providing the habitat that Blanding's Turtles require throughout the stages of their life cycle. All features that Hartwig and Kiviat (2007) found necessary for Blanding's Turtles habitat were present at our study site: basking sites, mucky substratum, and abundant emergent, floating, and submerged vegetation. Henning and Hinz (2016) found that Blanding's Turtles avoided habitats with

abundant growth of cattails (*Typha sp.*), however, we recorded seasonal use of predominantly cattail marsh habitat in two individual females (#2 and #11). Blanding's Turtles at Fawn Lake Ranch use a landscape relatively unaltered by human activity. No herbicides or pesticides were presently being used that could lower habitat quality for turtles. Water bodies appeared to have high biological productivity and supported an abundance of aquatic plants and macroinvertebrates. Wetland sites were mostly surrounded by available nesting habitats. Wetlands and upland habitats were unfragmented and generally unaltered by activities of a small human population and bison management. Survivorship of adult turtles appeared to be at sustainable levels. We documented two mortalities of Blanding's Turtles: one juvenile and one adult male. These deaths were documented along wetland edges, away from roads, and were assumed to have occurred naturally. The body of the juvenile was fully in-tact, while soft tissues of the adult male were absent from the shell. Over half (55%) of Blanding's Turtles captured in this study were juveniles, suggesting that younger turtles were being recruited into the population. An absence of or rarity of juveniles has been noted in other studies (Graham and Doyle 1977, Kofron and Shreiber 1985, Congdon and van Loben Sels 1991, Rubin et al. 2004). Although turtles do not appear to be limited by available resources (e.g., preferred habitat, food), continued monitoring is needed to ensure sympatric, generalist species like Painted Turtles and Snapping Turtles are not outcompeting Blanding's Turtles (Panella and Rothe-Groleau 2021). Buffers around wetland habitats may need to be considered when practices such as fire, heavy grazing, and mowing take place during the active season (Panella and Rothe-Groleau 2021). Especially during hot

and dry periods, Blanding's Turtles may be inconspicuously located along wetland edges from late May to early August. Under these drought conditions, use of vehicles/ATVs along wetland edges should be discouraged. These management practices still require scientific evaluation prior to implementation on a large scale (Panella and Rothe-Groleau 2021). Nesting locations need to be identified at our study site. At nesting sites in upland habitats, we discourage use of vehicles/ATVs during the nesting season (Panella and Rothe-Groleau 2021).

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Table 1. Numbers of turtles captured in traps or opportunistically by hand at Fawn Lake Ranch, western Cherry County, Nebraska. Counts include recaptures, but only Blanding's Turtles (*Emydoidea blandingii*) were marked with individually coded notches in carapaces. Starting in June 2019, we did not purposely handle Ornate Box Turtles and Painted Turtles, thus these species were observed more times on the ranch during our study than noted in this table.

Scientific name	Species	Trap	Hand	*Total*
Chrysemys picta	Northern Painted Turtle	175	6	181
Emydoidea blandingii	Blanding's Turtle	36	9	45
Chelydra serpentina	Common Snapping Turtle	35	0	35
Terrapene ornata	Ornate Box Turtle	2	13	15
Kinosternon flavescens	Yellow Mud Turtle	1	3	4
Total		249	31	280

Table 2. Trap effort measured in days for each month of the two field seasons at Fawn Lake Ranch, western Cherry County, Nebraska.

	2019	2020	*Total*
May	244	191	435
June	361	471	832
July	363	483	846
Aug.	398	395	793
Sept.	248	0	248
Total	1,614	1,540	3,154

Table 3. Numbers of turtles captured in traps each year of study at Fawn Lake Ranch, western Cherry County, Nebraska. Counts include recaptures.

	2019	2020	*Total*
Northern Painted Turtle	90	85	175
Blanding's Turtle	17	19	36
Common Snapping Turtle	17	18	35
Ornate Box Turtle	2	0	2
Yellow Mud Turtle	1	0	1
Total	127	122	249

Table 4. Numbers of turtles captured per 100 trap nights adjusted for trap effort. Trap effort varied, with relative effort as large crab (60%), hoop (23%), and small crab (17%).

	Blanding's Turtle	Northern Painted Turtle	Common Snapping Turtle	Ornate Box Turtle	Yellow Mud Turtle	All turtles
Hoop	2.9	20.1	4.0	0.0	0.0	27.1
Large crab	0.4	0.9	0.2	0.1	0.1	1.6
Small crab	1.3	2.4	0.6	0.0	0.0	4.3

Table 5. Trap effort by site for 2019 and 2020 combined. * denotes sites where Blanding's Turtles were captured (see Fig. 2).

Site name	Trap effort (days)
Homestead*	1,276
East Holding*	584
West Holding*	361
Hill*	353
Headquarters*	230
Mail Route	118
Mally Lake	98
Beckwith	48
U-Cross	20
Radio Tower	16
Mally Lake and James	12
Rat Lake	12
C-Barr	10
Horse	8
Morgan Lake	8
Total	3,154

Table 6. Locations and measurements of 33 Blanding's Turtles (*Emydoidea blandingii*) captured at Fawn Lake Ranch in 2019 and 2020. Sex includes female (F), male (M), and unknown (U; presumed juvenile). Weights were measured in g and lengths in cm. Annuli reported in parentheses were worn and are underestimates of actual count. Turtles with radio transmitters denoted by *.

ID	Capture date	Lat	Long	Sex	Weight	Cara-pace length	Cara-pace width	Height	Plastron length	Plastron width	Annuli #
1	25-May-19	42.498	101.901	F	1250	19.8	13.5	8.4	19.1	14.0	16
2*	8-Jun-19	42.500	101.965	F	1275	21.2	14.5	8.5	20.0	11.5	14
3	9-Jun-19	42.486	101.889	U	640	16.4	11.0	6.9	16.0	8.5	9
4*	19-Jun-19	42.500	101.966	F	1295	21.0	14.0	8.5	21.0	11.0	(9+)
5	21-Jun-19	42.500	101.965	U	435	13.5	9.3	5.3	12.8	7.1	10
6	24-Jun-19	42.500	101.965	U	775	18.2	12.0	6.8	16.4	8.8	8
7	25-Jun-19	42.500	101.965	U	275	10.9	7.7	4.8	10.7	6.2	8
8*	26-Jun-19	42.487	101.887	F	1390	21.5	14.2	9.5	20.2	11.4	(14+)
9	27-Jun-19	42.503	101.982	U	390	13.4	9.4	4.9	12.9	6.6	5
10*	8-Jul-19	42.486	101.888	M	1040	21.0	14.0	6.1	18.0	10.0	10
11*	13-Jul-19	42.503	101.982	F	1525	22.0	15.0	9.5	21.5	12.3	(20+)
12*	29-Jul-19	42.486	101.889	M	1850	24.0	16.0	10.0	21.8	11.9	20+
13	1-Aug-19	42.500	101.965	U	220	10.2	7.2	3.6	9.8	5.1	6
14	12-Aug-19	42.500	101.965	U	395	12.5	8.3	4.9	11.8	6.5	10

15*	15-Aug-19	42.485	101.887	F	1630	22.0	14.5	9.2	22.0	11.8	(13+)
16	15-Aug-19	42.498	101.910	U	470	13.7	9.5	5.4	13.4	7.1	6
17*	16-Aug-19	42.502	101.953	M	1050	20.4	13.5	7.5	19.0	10.2	14+
18	17-Aug-19	42.486	101.888	U	175	9.6	7.1	3.5	9.2	5.1	4
19*	17-Aug-19	42.486	101.886	M	1290	21.9	14.0	8.9	19.0	10.2	17+
20*	30-Aug-19	42.501	101.937	F	1610	21.5	15.2	9.4	21.0	11.5	15+
21	18-Jun-20	42.484	101.883	U	210	10.7	8.1	4.5	10.1	5.8	5
22	18-Jun-20	42.502	101.939	U	450	13.9	9.5	5.6	13.7	7.1	7
23	23-Jun-20	42.502	101.939	U	700	16.8	12.0	6.6	15.9	8.5	11
24*	25-Jun-20	42.501	101.937	M	845	17.8	11.5	7.2	16.9	8.8	14
25	16-Jul-20	42.500	101.965	U	380	11.5	7.6	4.4	11.2	5.6	10
26*	22-Jul-20	42.486	101.889	F	1170	19.4	13.8	8.2	18.5	11.0	(20+)
27*	22-Jul-20	42.486	101.889	U	770	17.6	12.0	7.0	17.0	8.8	12
28*	26-Jul-20	42.487	101.888	M	1680	23.5	15.5	9.0	20.0	11.0	(20+)
29	26-Jul-20	42.484	101.889	U	260	8.3	5.0	1.3	8.2	3.1	5
30	26-Jul-20	42.485	101.889	U	140	6.4	4.2	0.6	5.9	1.7	3
31	28-Jul-20	42.485	101.889	U	515	15.0	10.2	6.2	14.8	7.8	10
32	11-Aug-20	42.486	101.886	U	180	10.4	8.0	4.4	9.6	5.5	4
33	25-Sep-20	42.464	101.790	M	853	19.0	14.0	6.0	16.8	10.0	(20+)

Table 7. Mean ± SE (range) for body size measurements for female (n = 8), male (n = 7), and unknown (presumed juvenile, n = 18) Blanding's Turtles (*Emydoidea blandingii*) at Fawn Lake Ranch, western Cherry County, Nebraska.

	Female	Male	Unknown
Weight (g)	1393 ± 62 (1170 – 1630)	1230 ± 150 (845 – 1850)	410 ± 48.4 (140 – 775)
Carapace length (cm)	21.1 ± 0.3 (19.4 - 22.0)	21.1 ± 0.9 (17.8 - 24.0)	12.7 ± 0.8 (6.4 – 18.2)
Carapace width (cm)	14.3 ± 0.2 (13.5 – 15.2)	14.1 ± 0.6 (11.5 – 16.0)	8.8 ± 0.5 (4.2 – 12.0)
Height (cm)	8.9 ± 0.2 (8.2 – 9.5)	7.8 ± 0.6 (6.0 – 10.0)	4.8 ± 0.4 (0.6 – 7.0)
Plastron length (cm)	20.4 ± 0.4 (18.5 – 22.0)	18.8 ± 0.7 (16.8 – 21.8)	12.2 ± 0.4 (5.9 – 17.0)
Plastron width (cm)	11.8 ± 0.3 (11.0 – 14.0)	10.3 ± 0.4 (8.8 – 11.9)	6.4 ± 0.5 (1.7 – 8.8)

Table 8. Dates of recaptures for Blanding's Turtles (*Emydoidea blandingii*) following initial capture at Fawn Lake Ranch, western Cherry County, Nebraska.

ID	Original capture	Recapture 1	Recapture 2	Recapture 3
2	8 June 2019[H]	19 July 2020[R]		
4	19 June 2019[H]	23 June 2019[T]		
5	21 June 2019[T]	25 June 2019[T]	27 June 2019[T]	
8	26 June 2019[T]	19 July 2020[R]		
10	8 July 2019[T]	24 June 2020[R]	13 Aug 2020[T]	
11	13 July 2019[T]	28 June 2020[T]	29 June 2020[T]	19 July 2020[R]
12	29 July 2019[T]	24 July 2020[T]		
15	15 Aug 2019[T]	18 June 2020[R]	27 July 2020[R]	
16	15 Aug 2019[H]	16 Aug 2019[H]		
17	16 Aug 2019[H]	19 July 2020[R]		
19	17 Aug. 2019[H]	24 June 2020[R]		
20	30 Aug. 2019[H]	1 June 2020[R]	19 July 2020[R]	
21	18 June 2020[H]	15 Aug. 2020[T]		
22	18 June 2020[T]	20 June 2020[T]		
24	25 June 2020 [T]	18 July 2020[R]		
26	22 July 2020[T]	5 Aug. 2020[T]	8 Aug. 2020[T]	

Notes: [H]opportunistic captures by hand; [R]captures from telemetry tracking; and [T]captures in traps.

Table 9. Total numbers of Blanding's Turtles (*Emydoidea blandingii*) observed escaping from modified and unmodified traps.

Trap Type	Escape	No escape	*Total*
Modified	3	4	7
Unmodified	2	1	3
Total	5	5	10

Table 10. Distance between Blanding's Turtle (*Emydoidea blandingii*) locations in late October and mid-January for both years of study, discerned by radio telemetry, at Fawn Lake Ranch, western Cherry County, Nebraska. "-" indicate no data recorded due to turtle not yet being captured.

		Distance (m) moved between dates	
Pasture	**Turtle #**	31 Oct. 2019 – 19 Jan. 2020	31 Oct. 2020 – 18 Jan. 2021
East Holding	2	9.4	19.2
	17	16.8	43.3
	20	156.1	20.3
Homestead	8	9.5	5.9
	10	123.4	34.3
	12	7.1	2.7
	15	6.9	10.5
	19	70.8	4.0
	26	-	1.4
	27	-	11.6
	28	-	166.6

Table 11. Duration of radio telemetry observations with total number of points and home range sizes of 13 individual Blanding's Turtles (*Emydoidea blandingii*) monitored at Fawn Lake Ranch in Nebraska. For sex, M represents male, F is female, and J is juvenile.

Turtle ID	Sex	Tracking dates	Total points	Home range size (ha)
2	F	8 June 2019 - 24 May 2021	25	47.2
4	F	19 June 2019 - 28 October 2019	22	62.6
8	F	26 June 2019 - 24 May 2021	40	26.5
10	M	8 July 2019 - 24 May 2021	34	5.9
11	F	13 July 2019 - 25 May 2021	10	29.1
12	M	28 July 2019 - 24 May 2021	26	10.6
15	F	15 August 2019 - 24 May 2021	29	6.6
17	M	16 August 2019 - 24 May 2021	22	17.8
19	M	17 August 2019 - 24 May 2021	26	7.8
20	F	30 August 2019 - 24 May 2021	26	3.7
26	F	22 July 2020 - 24 May 2021	10	0
27	J	22 July 2020 - 24 May 2021	11	12.2
28	M	26 July 2020 - 24 May 2021	9	1.4

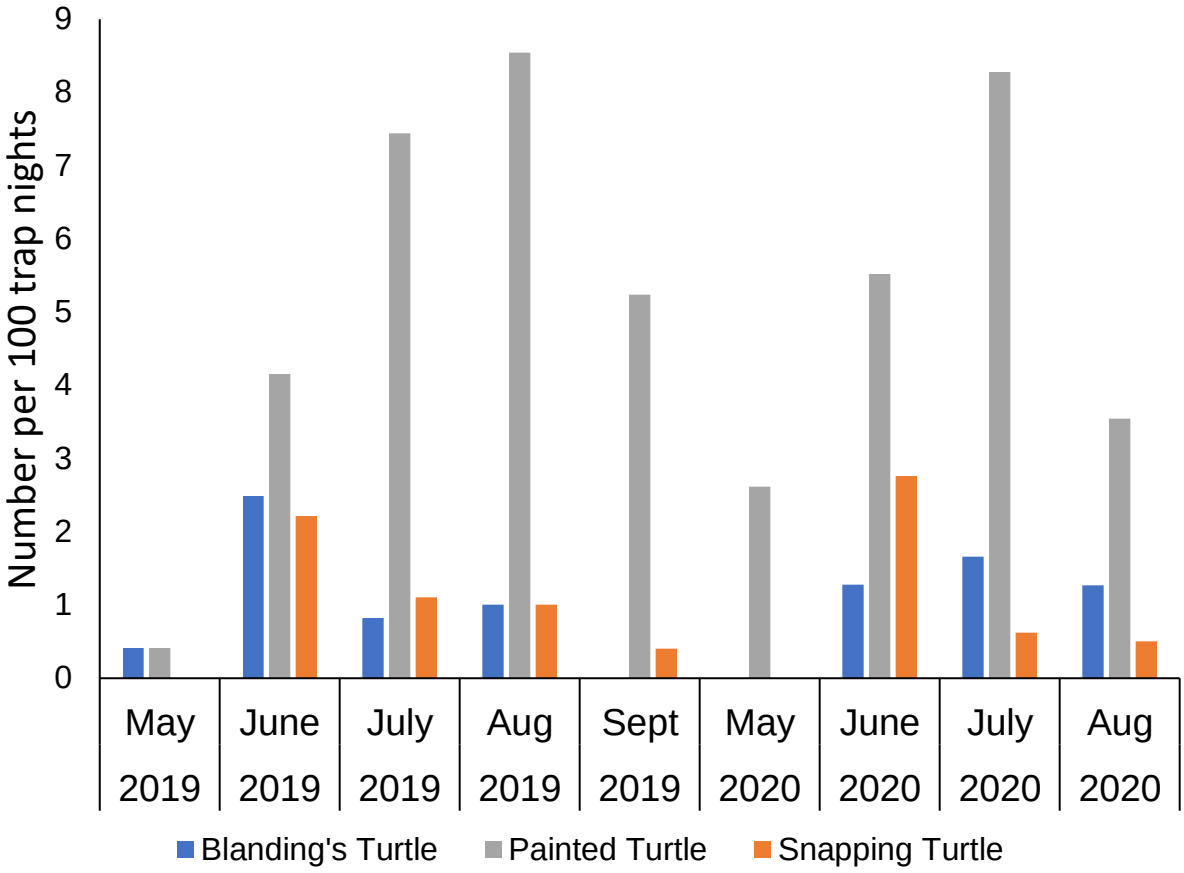


Figure 1. Number of individuals for three commonly captured species adjusted for trap effort each month of survey at Fawn Lake Ranch, western Cherry County, Nebraska.

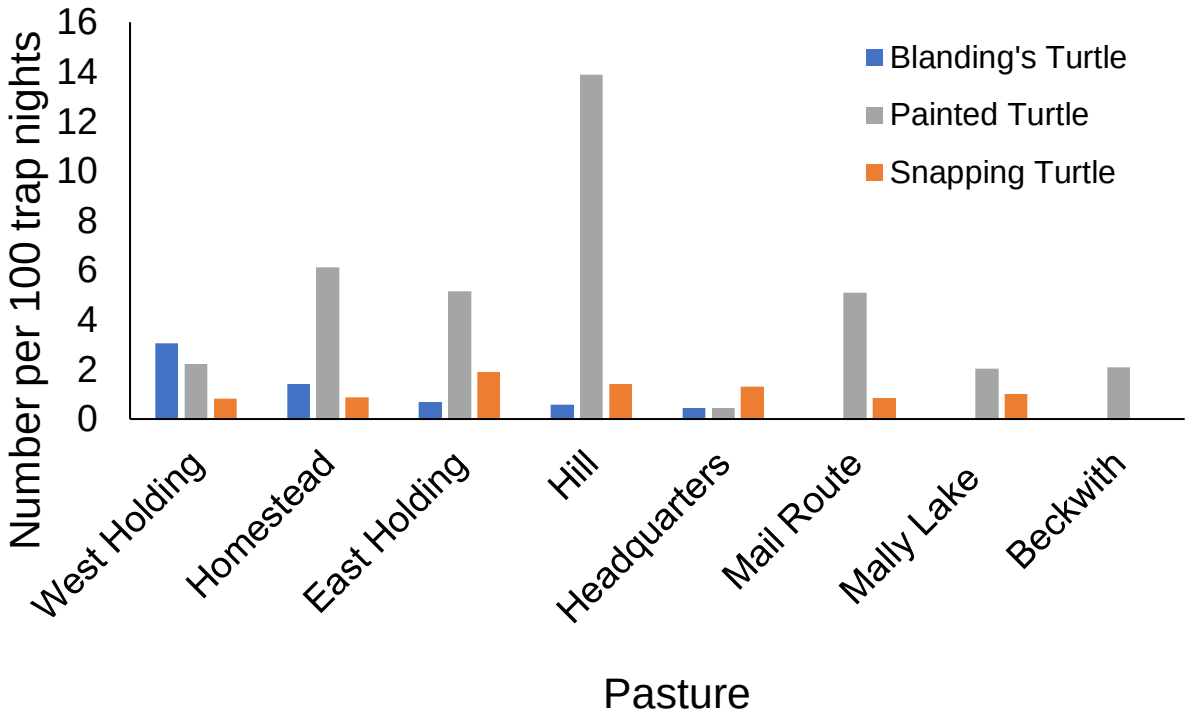


Figure 2. Number of individuals captured per 100 trap nights relative to trapping effort by pasture at Fawn Lake Ranch, western Cherry County, Nebraska.

Figure 3. Example of damage by other animals to crab traps baited for turtles on 22 July 2020. A large hole was present in the netting of a small crab trap placed at the edge of a wetland (left). Bait was physically removed from trap and found along wetland edge with all contents eaten (right).

Figure 4. Snail biomass along drying wetland shoreline (left) and bottom of small crab trap (right) in June 2020.

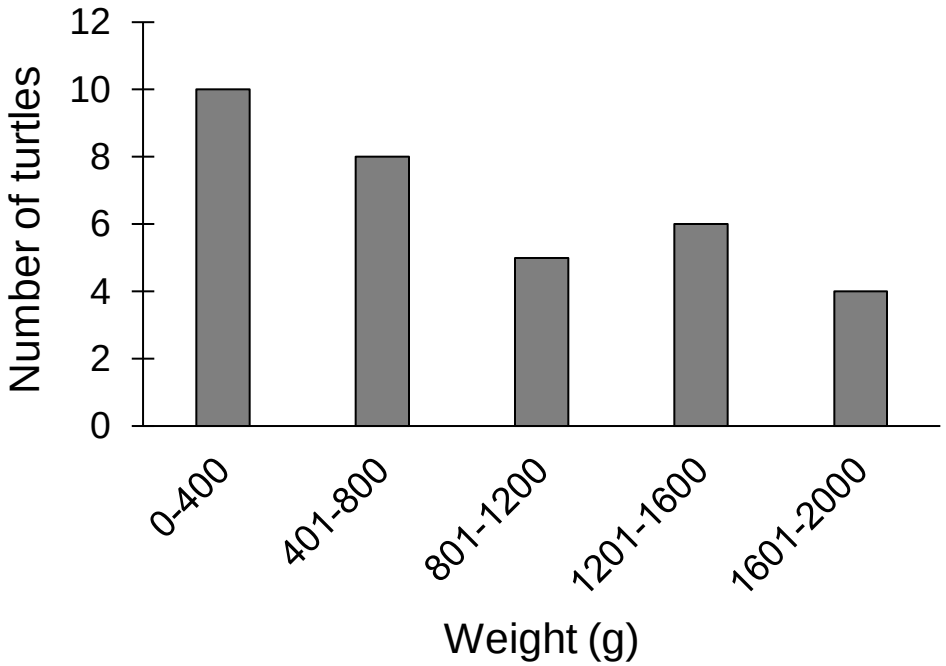


Figure 5. Frequency distribution of weights of Blanding's Turtles (*Emydoidea blandingii*) at Fawn Lake Ranch, western Cherry County, Nebraska. Individuals were considered juveniles at < 800 g.

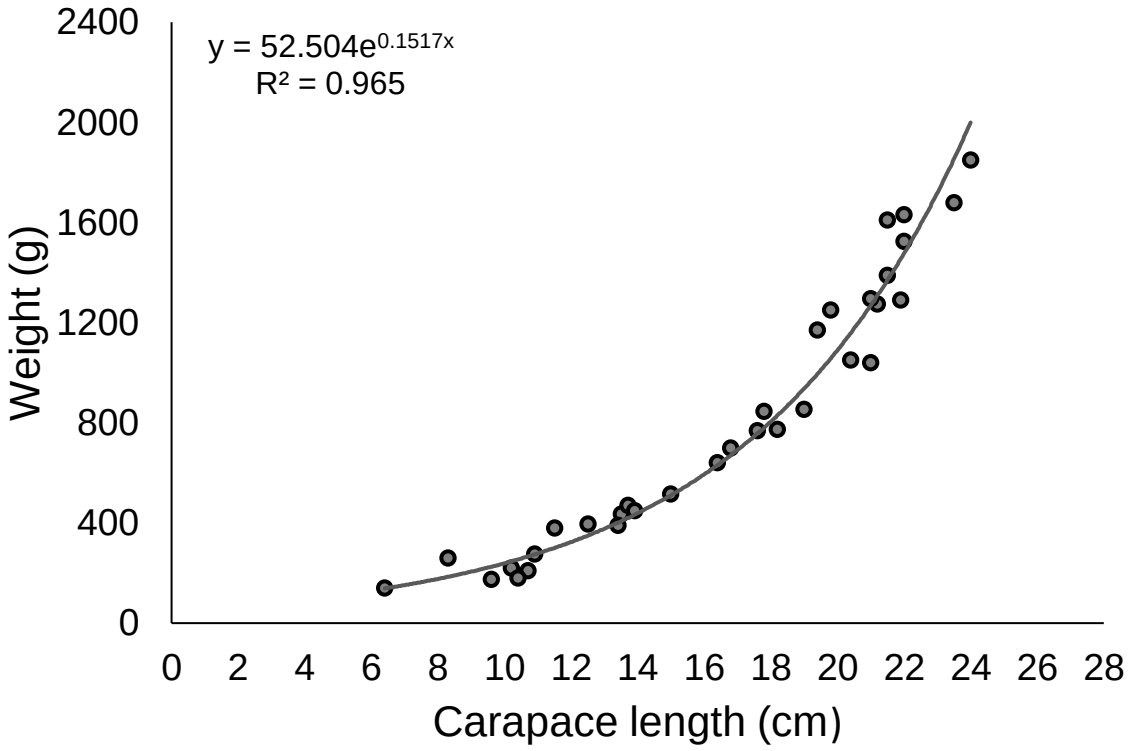


Figure 6. Relationship between carapace length and weight for 33 Blanding's Turtles (*Emydoidea blandingii*) captured at Fawn Lake Ranch, western Cherry County, Nebraska, in 2019 and 2020. Generally, turtles with a carapace length around 18 cm were considered adults, which corresponds to a weight of about 800 g in our study area, were considered adults.

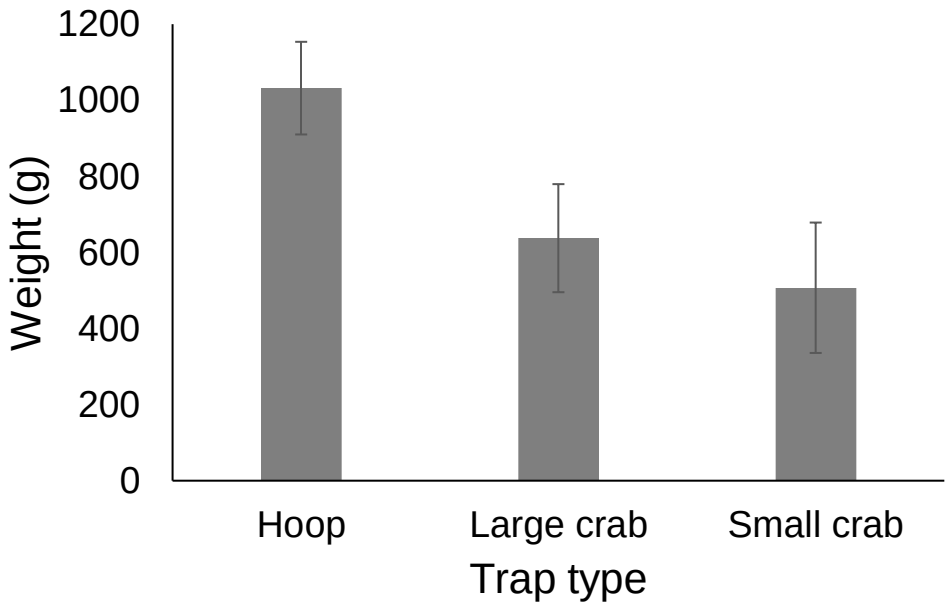


Figure 7. Mean weights (SE) of Blanding's Turtles (*Emydoidea blandingii*) captured in each type of trap (hoop *n* = 21; large crab *n* = 8; small crab *n = 7*) at Fawn Lake Ranch, western Cherry County, Nebraska.

Figure 8. Top-down (left) and ground-level (right) views of adult female (#8) Blanding's Turtle (*Emydoidea blandingii*) on land within grassland vegetation near edge of pond in Homestead Pasture on 26 June 2020.

Figure 9. Top-down (left) and ground (right) views of adult female (#11) Blanding's Turtle (*Emydoidea blandingii*) on land within grassland vegetation between wetland sites in West Holding pasture on 17 and 19 July 2020.

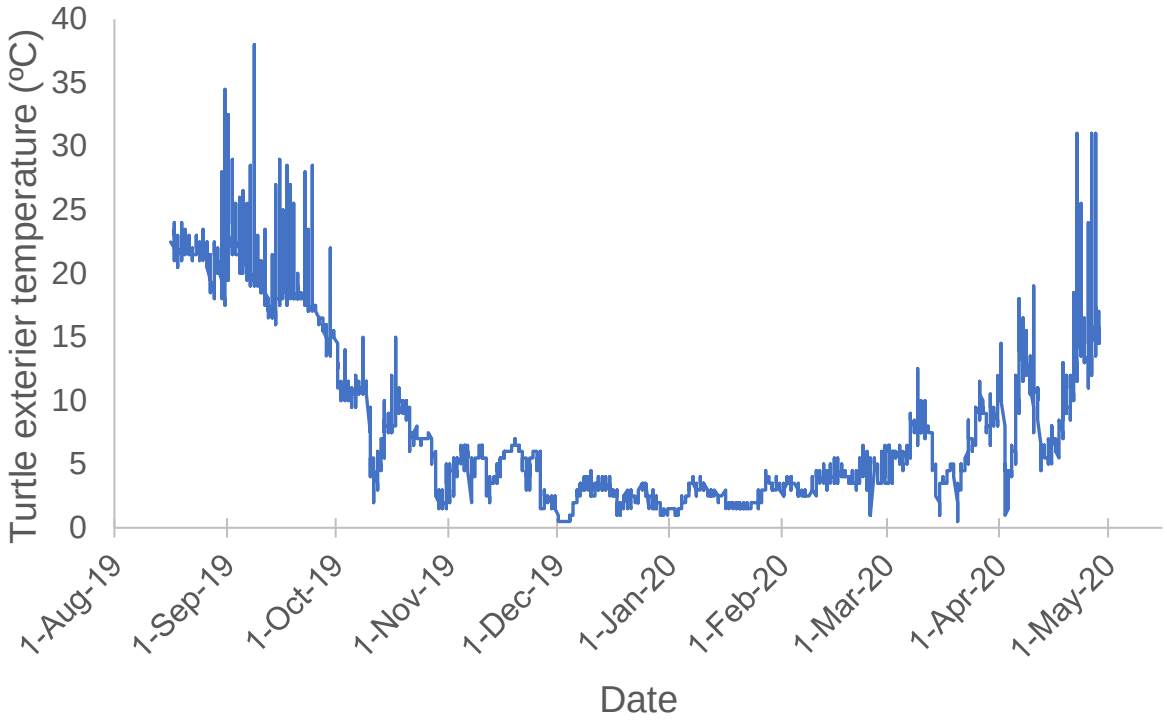


Figure 10. Exterior temperature of adult female (#20) Blanding's Turtle (*Emydoidea blandingii*) from autumn 2019 through spring 2020 at Corral Lake.

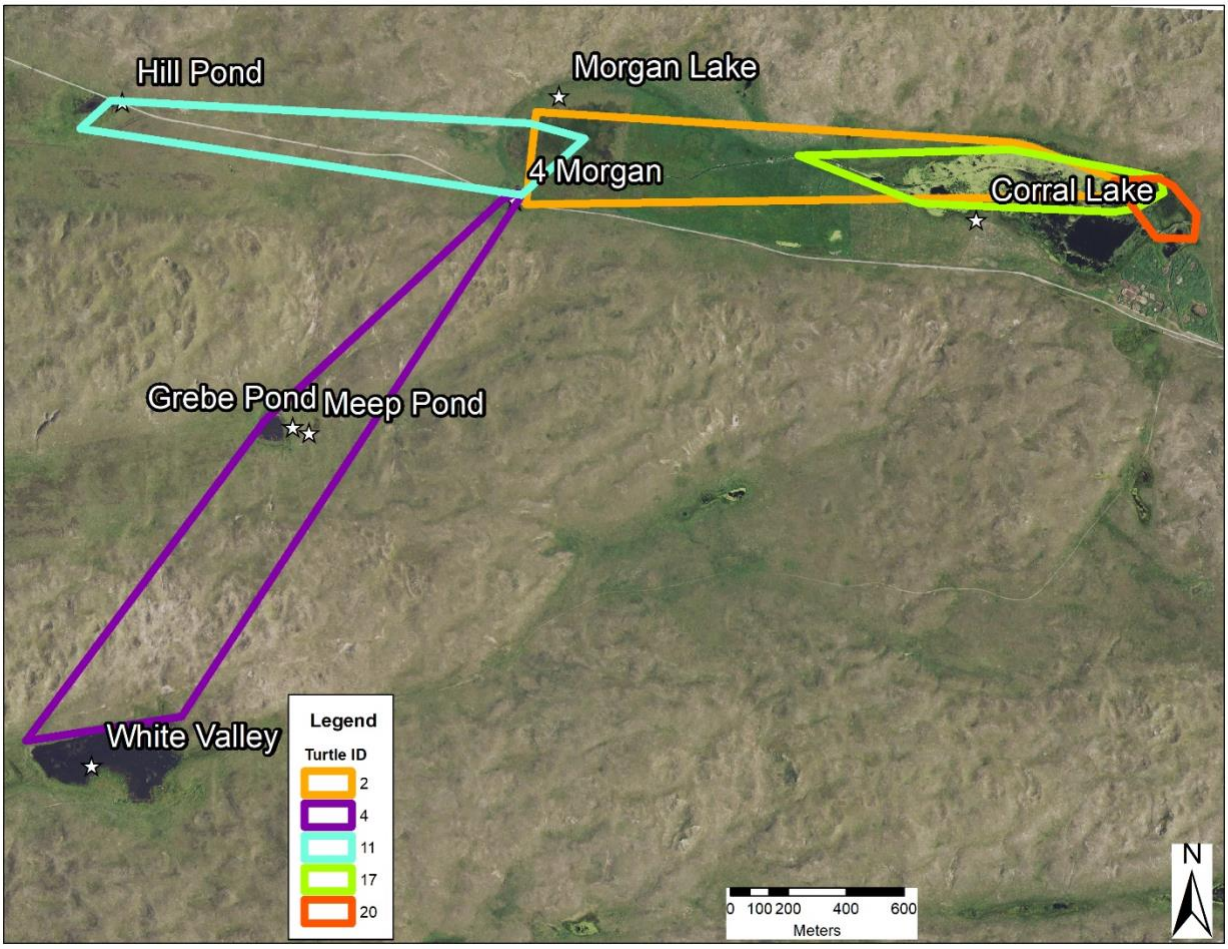


Figure 11. Space use displayed of Minimum Convex Polygons of four adult females (#2, #4, #11, #20) and one adult male (#17) Blanding's Turtle (*Emydoidea blandingii*) at Fawn Lake Ranch, western Cherry County, Nebraska.

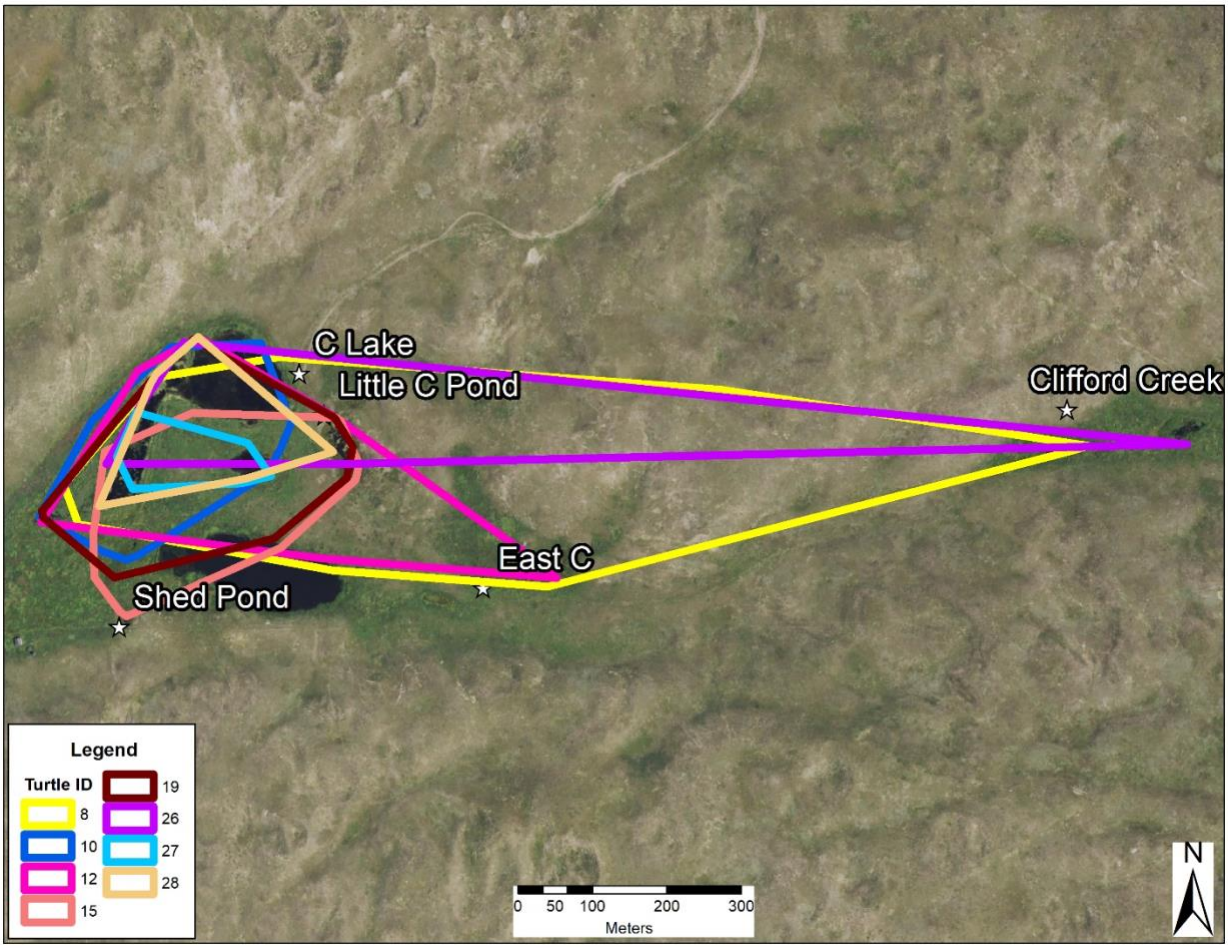
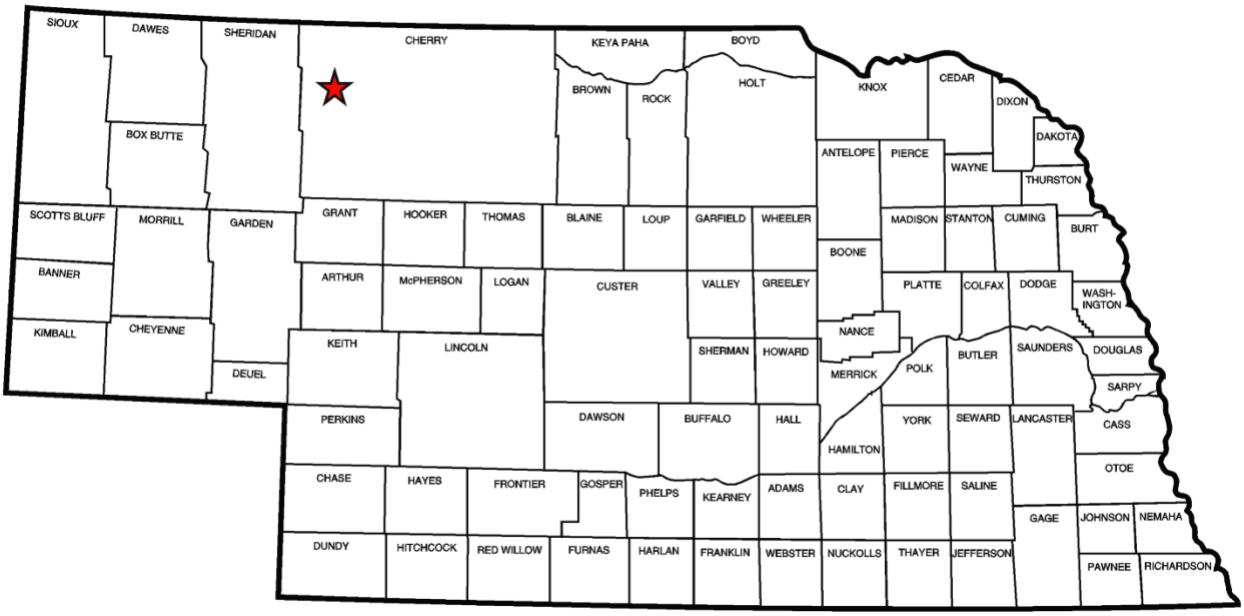


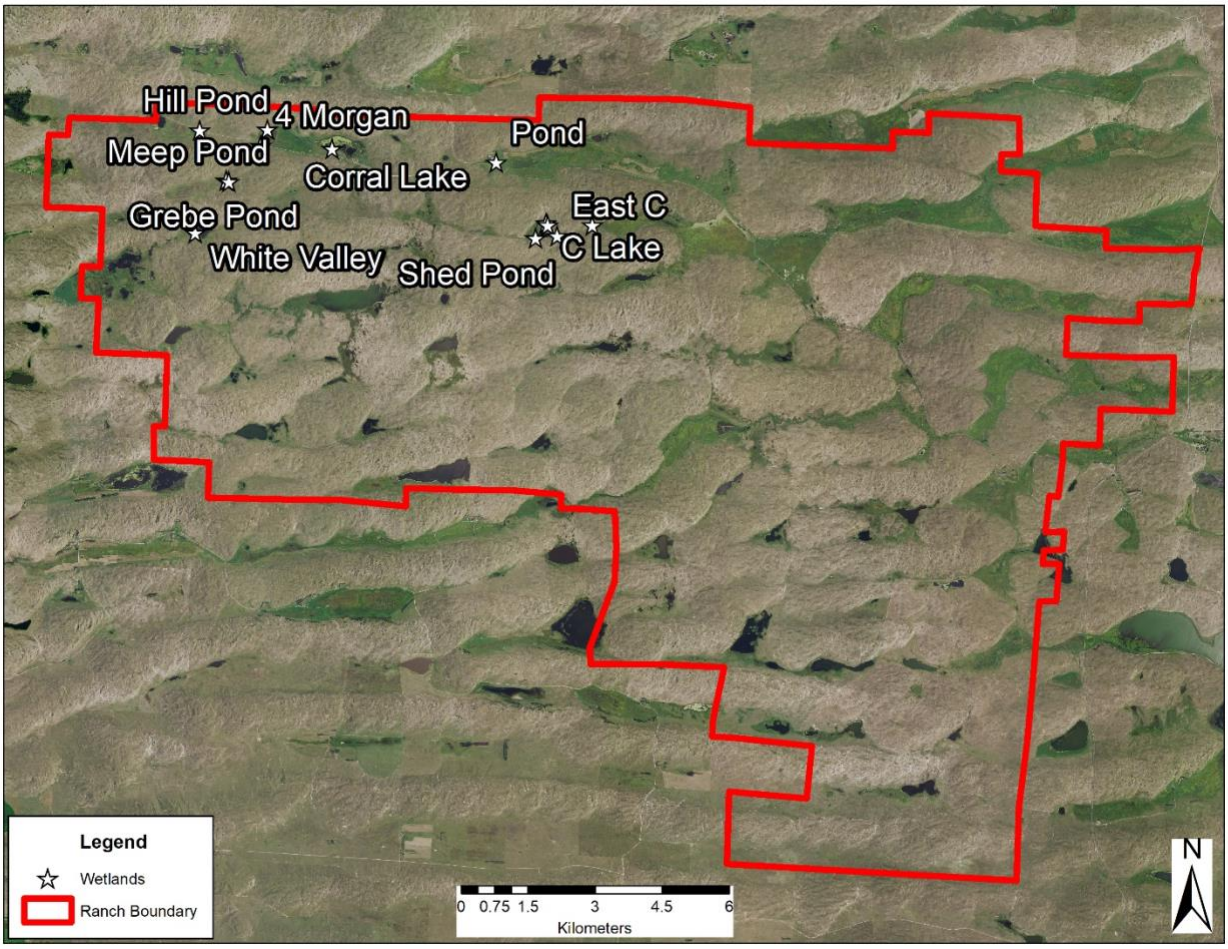
Figure 12. Space use displayed as Minimum Convex Polygons for three adult females (#8, #15, #26), four adult males (#10, #12, #19, #28) and one juvenile (#27) Blanding's Turtles (*Emydoidea blandingii*) at Fawn Lake Ranch, western Cherry County, Nebraska.

Appendix A

Study Site Maps and Images



General location of Fawn Lake Ranch, western Cherry County, Nebraska.



Property boundary of Fawn Lake Ranch, western Cherry County, Nebraska with key sampling locations for Blanding's Turtles (*Emydoidea blandingii*) labeled.

Representative spring and summer photos of sites where Blanding's Turtles (*Emydoidea blandingii*) were captured at Fawn Lake Ranch, western Cherry County, Nebraska. *Clockwise from top left*: East Holding Pasture (southern perspective of Corral Lake from northwest side, 18 June 2020, photo by L. Wal); Homestead Pasture (west-facing view from east corner of C Lake, 27 May 2020); East Holding Pasture (east-facing view from north side of Corral Lake, 11 May 2019), and West Holding Pasture (east-facing view from west corner of 4 Morgan site, 4 August 2020).

Representative winter photos of sites where Blanding's Turtles were located by tracking with radio telemetry. *Clockwise from top left*: East Holding Pasture (east-facing view from north side of Corral Lake, 31 October 2020); East Holding Pasture (eastern perspective of Corral Lake from south side, 18 January 2021); West Holding Pasture (north-facing view of 4 Morgan site, 19 January 2020); and Homestead Pasture (north-facing view of C Lake, 31 October 2020).

Appendix B

Project Data Sheets

Site Description Sheet

Ranch: _____ Pasture: _____ Site Name: _____

Date (yyyy_mm_dd): _____ Time (MDT): _____ 24 hr. Observers: _____

Location description: _____

Vegetation description:_____

Emergent vegetation: □ Y □ N Floating or submerged vegetation/moss/algae: □ Y □ N Substratum: □ soft □ medium □ hard

Muskrat structures present: □ Y □ N Structure #: _____ Muskrat animal count # _____

Muskrat notes: _____

Coordinates (DD): N_____ W_____ Site described previously: □ Y □ N

Key photos taken: □ Site without person □ Site with person □ North □ South □ East □ West Other photos taken: □ Y □ N

Photo notes: _____

Size measurement: □ Rangefinder □ GIS If GIS, image date: _____

Rangefinder: Wetland length (m): _____ Wetland width (m): _____

Google Earth: Wetland length (m): _____ Wetland width (m): _____

General notes: _____

Site Sketch

Ranch: _____ Pasture: _____ Site Name: _____ Date: _____

Site sketch: Photo point North arrow X = Trap (w/#) O Muskrat structures || Emergent vegetation Windmill

Trap Set

Ranch: ___________ Pasture: _____________ Site Name: _________________________

Observers: _______________________ Tag #: ______ Type: □ Lg Crab □ Sm Crab □ Hoop

Coordinates (DD): N___________________________ W____________________________

Date set: ____________ Time set: ______ Date pulled: ____________ Time pulled: _________

Notes: ____

____

Ranch: ___________ Pasture: _____________ Wetland Name: _________________________

Observers: _______________________ Tag #: ______ Type: □ Lg Crab □ Sm Crab □ Hoop

Coordinates (DD): N___________________________ W____________________________

Date set: ____________ Time set: ______ Date pulled: ____________ Time pulled: _________

Notes: ____

____

Ranch: ___________ Pasture: _____________ Wetland Name: _________________________

Observers: _______________________ Tag #: ______ Type: □ Lg Crab □ Sm Crab □ Hoop

Coordinates (DD): N___________________________ W____________________________

Date set: ____________ Time set: ______ Date pulled: ____________ Time pulled: _________

Notes: ____

____

Ranch: ___________ Pasture: _____________ Wetland Name: _________________________

Observers: _______________________ Tag #: ______ Type: □ Lg Crab □ Sm Crab □ Hoop

Coordinates (DD): N___________________________ W____________________________

Date set: ____________ Time set: ______ Date pulled: ____________ Time pulled: _________

Notes: ____

____

Site Visit

Ranch: _____ Pasture: _____ Site Name: _____

Date: _____ Time (MDT): _____ 24 hr. Observers: _____

Air temp (°C): _____ Water temp. (°C): _____ Cloud cover □ none □ part □ full

Turtle(s) present: □ No □ Out of trap □ In trap □ Both in & out

EMBL # *not in traps*: _____ CHPI # *not in traps*: □ none □ some □ many

Animals on muskrat structure notes: _____

Animals on muskrat structure photos taken □ Y □ N Other photos taken □ Y □ N

Other notes:_____

Ranch: _____ Pasture: _____ Site Name: _____

Date: _____ Time (MDT): _____ 24 hr. Observers: _____

Air temp (°C): _____ Water temp. (°C): _____ Cloud cover □ none □ part □ full

Turtle(s) present: □ No □ Out of trap □ In trap □ Both in & out

EMBL # *not in traps*: _____ CHPI # *not in traps*: □ none □ some □ many

Animals on muskrat structure notes: _____

Animals on muskrat structure photos taken □ Y □ N Other photos taken □ Y □ N

Other notes:_____

Ranch: _____ Pasture: _____ Site Name: _____

Date: _____ Time (MDT): _____ 24 hr. Observers: _____

Air temp (°C): _____ Water temp. (°C): _____ Cloud cover □ none □ part □ full

Turtle(s) present: □ No □ Out of trap □ In trap □ Both in & out

EMBL # *not in traps*: _____ CHPI # *not in traps*: □ none □ some □ many

Animals on muskrat structure notes: _____

Animals on muskrat structure photos taken □ Y □ N Other photos taken □ Y □ N

Other notes:_____

Trap Animals

Ranch	Pasture	Site name	Trap tag #	Date	Time	EMBL#	CHPI#	CHSE#	Other (Y/N)	Notes

Turtle Data Sheet

Ranch: _____ Pasture: _____ Site Name: _____

Date: _____ Capture time: _____ 24 hr. Observers: _____

Capture method: □ Hand □ Trap Turtle status: □ Alive □ Dead Trap tag #: _____

Coordinates (if not in trap): N _____, W _____

Species: □ EMBL □ CHPI □ KIFL Sex: □ M □ F □ Unknown Gravid: □ Y □ N □ Unknown

---

Weight (g): _____ Carapace length (cm): _____ Carapace width (cm): _____

Height (cm): _____ Plastron length (cm): _____ Plastron width (cm): _____

Annuli #: _____ Annuli visible: □ Y □ N □ NA Annuli notes: _____

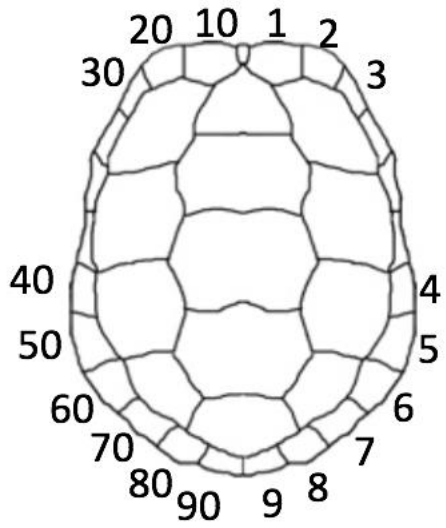
Photos: □ Carapace □ Plastron □ Head □ Annuli w/ ruler Photo notes: _____

Recapture □ Y □ N Marked ID: _____

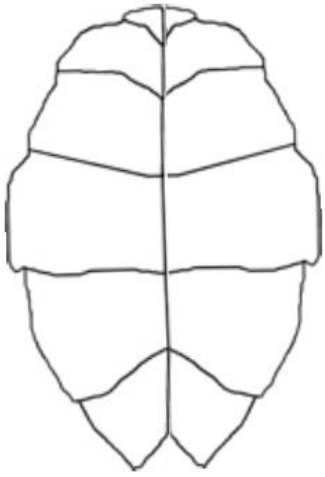
Transmitter: □ Y □ N Radio Frequency: _____ Temp. logger: □ Y □ N

Draw characteristics: Notches, markings, deformities, irregular scutes, injuries, scars, etc.

Carapace (Top View)



Plastron (Bottom View)



Notes:

Radio Tracking Locations—Blanding's Turtle

Marked ID: _____ Radio Frequency: _____ Observers: _____

Ranch: _____ Pasture: _____ Date: _____ Time: _____

Coordinates: N _____, W _____ GPS accuracy (m) _____

Habitat description:_____ Turtle behavior:_____

Photos taken □ Y □ N Notes:_____

Marked ID: _____ Radio Frequency: _____ Observers: _____

Ranch: _____ Pasture: _____ Date: _____ Time: _____

Coordinates: N _____, W _____ GPS accuracy (m) _____

Habitat description:_____ Turtle behavior:_____

Photos taken □ Y □ N Notes:_____

Marked ID: _____ Radio Frequency: _____ Observers: _____

Ranch: _____ Pasture: _____ Date: _____ Time: _____

Coordinates: N _____, W _____ GPS accuracy (m) _____

Habitat description:_____ Turtle behavior:_____

Photos taken: □ Y □ N Notes:_____

Marked ID: _____ Radio Frequency: _____ Observers: _____

Ranch: _____ Pasture: _____ Date: _____ Time: _____

Coordinates: N _____, W _____ GPS accuracy (m) _____

Habitat description:_____ Turtle behavior:_____

Photos taken: □ Y □ N Notes:_____

Chapter 2. Additional writings featuring turtles of the Sandhills

Abstract

This chapter features three separate works focused on turtles in Nebraska that I created during my graduate studies. These articles have built upon knowledge of Blanding's Turtles and Ornate Box Turtles in the state. Each piece served as an opportunity to communicate my research in different academic writing styles while supporting my interest in environmental education. The first is a creative writing piece planned for inclusion as a sidebar in an updated version of a book focused on the Nebraska Sandhills (Forrester in review). Highlighting Blanding's Turtles on more generally accessible platforms is important to increase awareness about the species and hopefully appreciation by the public. The second article reported underwater copulatory behavior in Ornate Box Turtles, a closely related species to Blanding's turtles (Forrester et al. 2020). I observed this behavior while I was carrying out research on Blanding's Turtles. This observation served as the first known record of underwater copulatory behavior in Ornate Box Turtles and was published in Transactions of the Nebraska Academy of Sciences. The third and final article is a geographic distribution note published in Herpetological Review. This note documented the westernmost record of Blanding's Turtles in Nebraska and extended the known distribution of *E. blandingii* to the northwest (Forrester et al. 2018). Herein I include the submission that is in review, and I invite readers to see the published versions of the other two works (Forrester et al. 2018, 2020). Collectively these works highlight the importance of being in field sites to

witness previously undocumented behaviors and space use by species, as well as a variety of writing styles that may be used to share observations.

Forrester, A. J. In review. Sidebar: Blanding's Turtles. *In* Nebraska Sandhills: An Atlas.

Forrester, A. J., Rohde, M. L., Harner, M. J., Kruse, C. and K. Geluso. 2020. Ornate Box Turtles (*Terrapene ornata*) copulating in water: an incidental observation or ancestral behavior. Transactions of the Nebraska Academy of Sciences 40:19-23.

Forrester, A.J., Geluso, K., Harner, M. J., and C. Kruse. 2018. Geographic distribution: *Emydoidea blandingii* (Blanding's Turtle). Herpetological Review 49: 711.

Forrester, A. J. *In review* Sidebar: Blanding's Turtles. *In* Nebraska Sandhills: An Atlas.

Within the Sandhills wetlands is a wild, ancient treasure. This colorful steward has an Oscar-winning smile and is an indicator of ecosystem health. I speak of the beloved Blanding's turtles of the Nebraska Sandhills.

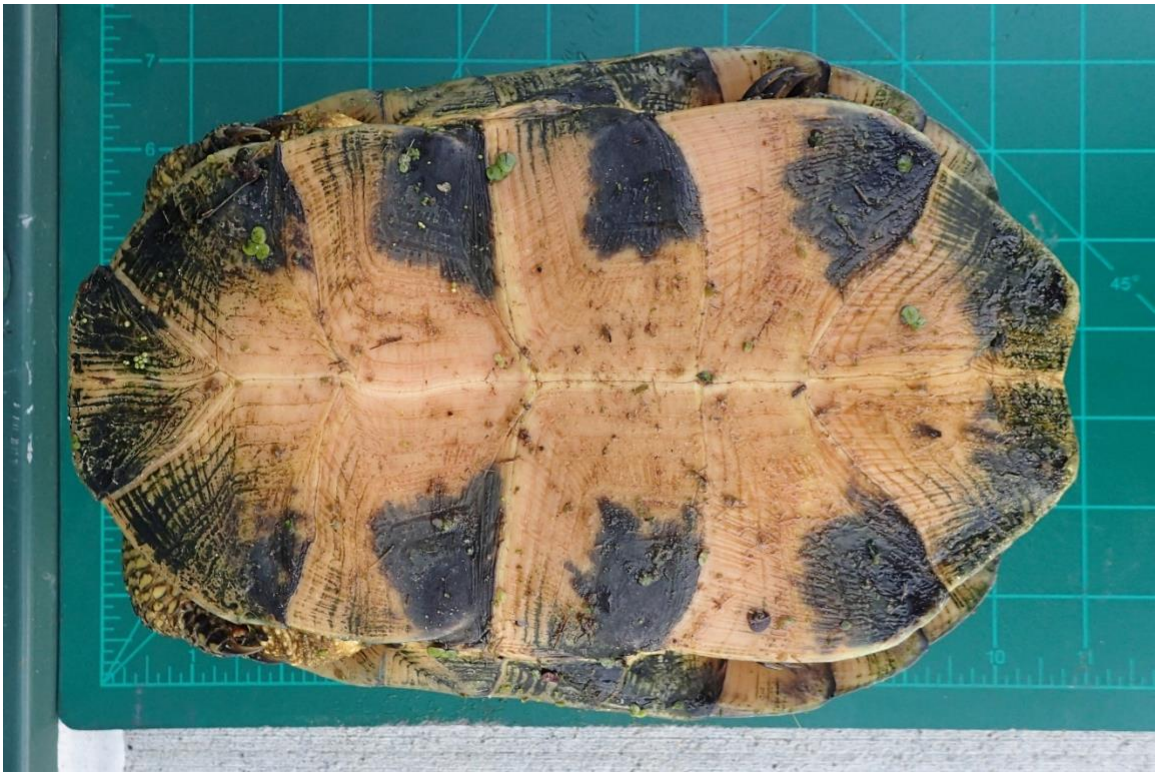
Blanding's turtles (*Emydoidea blandingii*) are a North American semiaquatic species whose range extends west into the Sandhills (Ernst and Lovich 2009; Forrester et al. 2018). This species is differentiated from other turtles by its bright, yellow coloration on neck and chin. The neck of a Blanding's turtle is reminiscent of a Brachiosaurus, notably long, with a clublike head and large, hazel eyes. The curvature of its mouth mimics a smile, earning the nickname "smileys" by some. Adults are about the size of a football, and their shells dome shaped. The top shell (carapace) is olive green to black in color with yellow speckling, and the bottom shell (plastron) is pale yellow with black splotches. This splotchy plastron pattern looks like a watercolor painting but acts like a thumbprint unique to each individual.

Blanding's turtles require a mosaic of wetland and upland habitats throughout their lives, and the Sandhills provide just that. The largest, most secure population of Blanding's turtles is located at Valentine National Wildlife Refuge. An estimated 137,000 Blanding's turtles were supported there in the early 2000s (Lang 2004). Other large, stable populations occur in Michigan and Minnesota (Congdon and Keinath 2006; Congdon et al. 2008), but Nebraska is the only state that lists the species as secure

(Schneider et al. 2018). In all states and provinces throughout its range, Blanding's turtles are listed as a species of conservation concern (Congdon and Keinath 2006; COSEWIC 2016; Schneider et al. 2018). There are many threats to their survival, but alteration and destruction of habitats are primary contributors of population declines (Congdon and Keinath 2006; Congdon et al. 2008; Ernst and Lovich 2009). The Sandhills remain relatively unaltered, sparsely populated by humans and, apart from roads, suitable habitats for Blanding's are still connected. Intactness of Sandhills ecosystems renders it the last stronghold for Blanding's turtles, an important conservation hotspot in the state. Interconnectedness of habitat complexes combined with continued monitoring and collaborative management is needed to maintain abundance of this reptile. Blanding's turtles are a special wildlife resource to this region, and an important indicator of ecosystem health for other populations.

May we protect our smileys.

A juvenile Blanding’s Turtle with their distinctive yellow chin.



Example of unique pattern on the plastron (bottom shell) of an adult Blanding's Turtle.

Two Painted Turtles (left) and Blanding’s Turtle (right) basking on a muskrat structure.

Literature Cited

Congdon, J. D., Graham, T. A., Herman, T. B., Lang, J. W., Pappas, M. J., and Brecke, B. J. 2008. *Emydoidea blandingii* (Holbrook 1838): Blanding's Turtle. Conservation Biology of Freshwater Turtles and Tortoises, Chelonian Research Monographs 5: 015.1-015.12.

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Forrester, A.J., K. Geluso, M.J. Harner, and C. Kruse. 2018. Geographic distribution: *Emydoidea blandingii* (Blanding's Turtle). Herpetological Review 49: 711.

Lang, J. W. 2004. Blanding's Turtles on Valentine NWR, Nebraska: population status, estimate of population size, and road mortality. Final Report for 2002-2003 Nebraska Department of Roads: Project EACNH-STPB-83-4(111), C.N. 80620 to USFWS.

Schneider, R., M. Fritz, J. Jorgensen, S. Schainost, R. Simpson, G. Steinauer, and C. Rothe-Groleau. 2018. Revision of the Tier 1 and 2 lists of species of greatest conservation need: a supplement to the Nebraska Natural Legacy Project State Wildlife Action Plan. The Nebraska Game and Parks Commission, Lincoln, NE. Available on-line:

http://outdoornebraska.gov/wp-content/uploads/2018/09/NE-SWAP-SGCN-Revision-Supplemntal-Document-2018-Final.pdf