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Weather--associated Triggers of Nesting Activity of Blanding's Turtles (Emydoidea blandingii) in Northeastern Illinois

Emma Buckardt

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Candidate for Bachelor of Science

Environmental Forest Biology

With Honors

December 2018

APPROVED

Thesis Project Advisor: ______________________

James P. Gibbs, Ph.D.

Second Reader: ______________________

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Honors Director: ______________________

William M. Shields, Ph.D.

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ABSTRACT— Environmental triggers of nesting activities in turtles are poorly known, but important for guiding species protection efforts. Blanding's Turtle (*Emydoidea blandingii*) is a species of concern throughout much of its range and is thought to prefer to nest on wet warm nights. Weather conditions during the nesting season were analyzed from 2013-2017 of a Blanding's Turtle population located within the Lake Plain of northeastern Illinois and southeastern Wisconsin to identity climate conditions most associated with nesting activity. Peak nesting dates each year were associated with warmer mean temperature in the preceding months of March, April, and May such that on warmer years the majority of turtles nested earlier. Within a given nesting season, nights in which nesting activity occurred had higher maximum ($\bar{x}$=27.6 C), mean ($\bar{x}$=21.9 C), and minimum temperatures ($\bar{x}$=15.9 C) than nights without nesting behavior. No pattern between nesting activity and precipitation was evident. Average barometric pressure was lower on nights with nesting activity (p=0.03). When the moon was in its brightest stages (Waxing Gibbous to Last Quarter), nesting behavior was more likely (p=0.0016). Nights when nesting occurred tended to have winds from the south (p=<0.001), which are generally associated with warmer temperatures and lower average air pressure in the study region. In conclusion, warmer nights with lower barometric pressure, brighter moon phase, and winds from the south appear to be drivers of nesting activity in Blanding's Turtles. These readily measured environmental triggers provide a useful guide to biologists to increase efficiency in finding and protecting nests and nesting females.

Key Words: Blanding's Turtle; Nesting; Nesting behavior; Weather conditions, Weather-associated trigger, Nesting activity

THE ENVIRONMENT in which an organism lives provides it with the resources necessary to survive and reproduce. In many organisms, environmental cues like temperature influence when nesting starts and the time between nesting events (Bowen et al. 2005). These include freshwater turtles, which are known to respond to various environmental cues like temperature, water currents, solar, and chemical cues to select and return to their activity center (Quinn and Graves 1998). Similarly, freshwater turtle species in North America and Australia have been documented to have different responses to weather conditions on nesting days and non-nesting days (Bowen et al. 2005). Variation in weather conditions over the nesting season can influence when individuals choose to nest. Painted turtles (*Chrysemys picta*) tend to the nest in the rain, possibly because the greater ease of in digging in wet soil, therefore reducing their time out of water (Bowen et al. 2005). Many freshwater turtles have temperature-dependent sex determination in which the temperature of the nest influences the sex ratio of the hatchlings. Because of this, the timing of nesting and location of nesting may influence the sex ratio in the nest (Standing et al. 1999).

The Blanding's Turtle (*Emydoidea blandingii*) is a semi-aquatic freshwater turtle that is listed as an endangered species in Illinois. Blanding's Turtles require both drier uplands and marshes to complete their reproductive life cycle. Blanding's Turtle populations have been in decline due to habitat loss and road mortality (Gibbs and Steen 2005; Millar and Blouin-Demers 2012). Road mortalities occur at a higher rate with females because they travel more frequently and at greater distances during their nesting forays (Gibbs and Steen 2005). Blanding's Turtles are long lived and become reproductively mature between 14 and 20 years of age, so it is critical for adult survival to keep a population stable (Congdon et al. 1993; Millar and Blouin-Demers 2012). The loss of females through road mortalities or other causes has a large impact on the population and research is needed to create better management plans to support their population (Condgon et al. 1993). Additional information is needed for how best to create self-sustaining viable populations and successfully minimize road mortalities by understanding nesting forays and nesting behavior (Congdon et al 1993; Congdon et al. 2000).

Understanding nesting behaviors and nest success of Blanding's Turtles, including the environmental cues for nesting, is important knowledge for conserving the species. Blanding's Turtles are often observed nesting (Synder 1921; Brown 1927; Bleakney 1963), but little research has focused on the weather conditions that trigger nesting behavior. Female Blanding's Turtles tend to nest near previous nesting locations or in similar habitat every year and likely use environmental cues to understand the nest site conditions through time (Congdon et al. 1983; Mui et al. 2016). Understanding when females nest and the weather cues that can trigger different nesting behavior can help scientists more efficiently document nesting. Few studies have looked at how weather conditions influence nesting behavior of turtles.

The goal of this study was to identify weather conditions that might serve as cues for nesting and non-nesting nights by Blanding's Turtles. I tested the theory that Blanding's Turtles typically nest on warm rainy nights (Rowe and Moll 1991; Standing et al. 1999; Frye et al. 2017). To do so, I analyzed weather conditions during the nesting season from 2013-2017 as observed as part of a long-term study in the Lake Plain Region of northeastern Illinois and southeast Wisconsin to determine which influenced when turtles nested and when they did not.

MATERIALS AND METHODS

This study was based on a dataset collected by the Lake County Forest Preserve District as part of their Blanding's Turtle Recovery Program, which has taken initiatives to protect nests and have harvested eggs for captive incubation. During the typical nesting period of June, technicians radio-tracked gravid adult females during the day to check for movement towards nesting sites and monitor the development of the eggs. Females were palpated in the inguinal region to monitor egg development (Congdon et al. 1983). At night the adult females that were determined most likely to nest, based on egg hardness and proximity to known nesting locations were monitored every night starting around 1900 hours and ending when the last turtle activity stopped. When a female was digging, a field technician recoded the coordinates of the nest attempt and checked the turtle periodically until oviposition was confirmed and the nest was covered or the hole was abandoned. Technicians tried to minimize disturbance. In other studies nest abandonment was most likely due to a potential threat of meso-predator, human observer, incorrect substrate, or loud trains passing (Illinois Natural History 20016; Frye et al. 2017). Between 2013-2017, 67 successful nesting attempts occurred and 59 nests were abandoned.

To examine associations between nesting activity and weather conditions, I gathered historical weather data from the Waukegan National Airport weather station (approximately 7 km from nesting sites) from Weather Underground (www.wunderground.com/history). Weather variables of interest included temperature, humidity, precipitation, air pressure, wind speed and direction, moon phase and percent illuminated and cloud cover throughout the day. It is important to note that the weather data was for the region and does not reflect specific microclimates near each nesting location. Nesting and associated weather conditions data is categorized into 3 different nesting activity types, inactivity during the nesting season of June, digging without oviposition, and digging with oviposition. The locations of nesting sites were evaluated as well (Appendix I).

I analyzed the factors hypothesized to affect nesting using unequal variance *t*-tests (for continuous dependent variables: maximum temperature, mean temperature, minimum temperature, average humidity, dew point, average air pressure, precipitation, wind speed and percent of the moon illuminated) and Chi-squared tests (for categorical dependent variables: wind direction, moon phase, cloud cover during the day and night). These tests were run in different combination of the three nest activity types to determine differences in weather between the nesting activity levels. I used correlation tests to analyze the change in Julian dates of nesting and average temperature of months previous to June. I used analysis of variance (ANOVA) to test if specific wind directions brought different maximum temperatures and precipitation. To synthesize results into a decision making tool, I created a regression tree to distinguish the strongest relationship between the activity types (oviposition, digging without oviposition, and inactive days in June) and the weather variables that were most significant (mean temperature, average air pressure, and moon phase). These relationships may give more information on how the weather variable can be used to make decisions. The regression tree was developed in R using the "party" package (Horthon et al. 2006).

RESULTS

During 2013-2017 average temperature of months prior to June was strongly correlated with the Julian date when females successfully nested. There was also a strong negative correlation between the date by which 90 percent of females nested and the average temperature of April and May (r=-.899, Figure 1.A) and similar patterns between the Julian date by which 50 percent of females nested and the average temperature of March, April, and May (r=-.873, Figure 1.B) and the Julian date by which 90 percent of females nested and the average temperature of March, April, and May (r=-0.811, Figure 1.C).

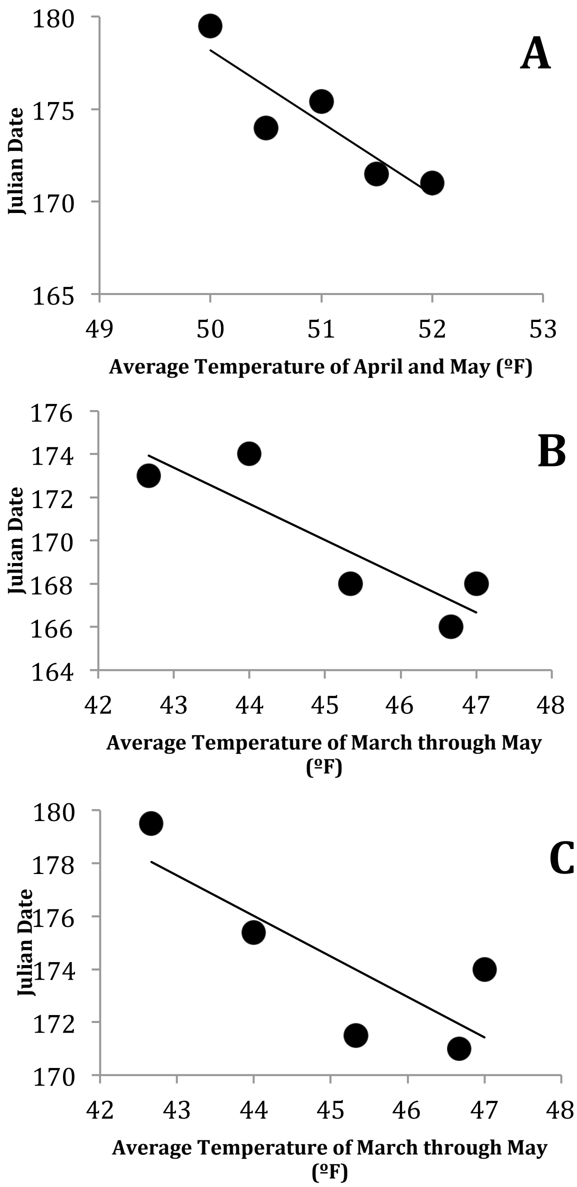

FIG. 1.—Correlations between nesting date (Julian dates) and the average temperature of months prior to the nesting month of June.

There was a difference between digging with and without oviposition for the maximum, mean, and minimum temperatures, air pressure and the percent of the moon illuminated (*p*=0.011, *p*=0.016, *p*=0.02, *p*=0.002, *p*=0.022, respectively, Table 1). There was also a difference between digging with oviposition and inactivity during the nesting duration for the maximum and mean temperature and air pressure (*p*=0.012, *p*=0.029, *p*= 0.028, respectively, Table 1). The variables that differ between digging without oviposition and inactivity during June are maximum, mean, and minimum temperature, dew point, air pressure, wind speed and percent of moon illuminated (*p*= <0.001, *p*= <0.001, *p*= <0.001, *p*= <0.001,*p*=<0.001, *p*=0.025, *p*=0.015, respectively, Table 1). Lastly, there was a difference of maximum, mean, and minimum temperature, air pressure, and dew point when comparing nesting behavior (pooled oviposition and digging without oviposition) and inactivity during June (*p*= <0.001, *p*= <0.001, *p*= <0.001,*p*=0.03, p= <0.001, respectively, Table 1).

Moon phase influenced occurrence of nesting activity (digging with and without oviposition p=0.042, digging with oviposition and Inactivity during nesting duration p=0.045, digging without oviposition and inactivity during June p= <0.001, nesting and inactivity during June p=0.0016, Table 2). Any nesting activity had a higher percentage of days that the moon was the brightest (Waxing Gibbous to Last Quarter). Digging without oviposition had a higher percent of days with a bight moon (77.97%) then digging with oviposition (61.19%). There was a difference in wind direction with the nesting activities having a higher percent of days with south winds and the inactive days having a higher percent of days with north winds (Digging with oviposition and inactivity during nesting duration p=0.002, Digging without oviposition and inactivity during June p= <0.001, Nesting and Inactivity during June p= <0.001, Table 2). There was a difference in the percent of clear days between digging with oviposition and inactivity during nesting duration (p=0.032, Table 2).

Table 1.—Continuous weather condition means ± SD for different categories of days within the 5 years of the study in Northeastern Illinois. Results from T-tests to compare the means between the different categories. Note that multiple females were seen digging with and without oviposition on the same day and those values are repeated.

Continuous variable	Digging and oviposition (n=67)	Digging without oviposition (n=59)	t	*p*	Digging and oviposition (n=67)	Inactivity during nesting duration (n=24)	t	*p*	Digging without oviposition (n=59)	Inactivity during June (n=105)	t	*p*	Nesting behavior (n=126)	Inactivity during June (n=105)	t	*p*
Maximum temperature (°C)	26.8 ± 3.8	28.5 ± 3.4	2.59	0.011	26.8 ± 3.8	23.8 ± 5.0	2.67	0.012	28.5 ± 3.4	23.3 ± 4.4	8.43	<0.001	27.6 ± 3.7	23.3 ± 4.4	7.94	<0.001
Mean temperature (°C)	21.2 ± 3.4	22.6 ± 3.2	2.45	0.016	21.2 ± 3.4	19.1 ± 4.0	2.27	0.029	22.6 ± 3.2	17.9 ± 3.6	8.62	<0.001	21.9 ± 3.4	17.9 ± 3.6	8.62	<0.001
Minimum temperature (°C)	15.3 ± 3.5	16.7 ± 3.3	2.35	0.021	15.3 ± 3.5	14.4 ± 3.8	1.02	0.31	16.7 ± 3.3	12.5 ± 3.8	8.06	<0.001	15.9 ± 3.5	12.5 ± 3.8	7.02	<0.001
Average humidity (%)	75.3 ± 8.1	72.9 ± 9.8	1.49	0.14	75.3 ± 8.1	78.8 ± 10.5	1.5	0.14	72.9 ± 9.8	73.5 ± 9.5	0.95	0.67	74.1 ± 8.9	73.5 ± 9.5	0.49	0.62
Dew point (°C)	16.3 ± 3.1	16.9 ± 2.9	1.17	0.24	16.3 ± 3.1	15.2 ± 3.8	1.34	0.19	16.9 ± 2.9	12.8 ± 3.9	7.65	<0.001	16.6 ± 3.0	12.8 ± 3.9	8.17	<0.001
Average air pressure (mmHg)	759.0 ± 3.4	757.1 ± 3.4	3.19	0.002	759.0 ± 3.4	760.5 ± 2.4	2.25	0.028	757.1 ± 3.4	760.0 ± 3.2	5.52	<0.001	758.2 ± 3.5	760.0 ± 3.2	2.19	0.03
Precipitation (Cm)	0.494 ± 0.86	0.417 ± 0.73	0.54	0.59	0.494 ± 0.86	0.452 ± 0.81	0.21	0.83	0.42 ± 0.73	0.33 ± 0.82	0.10	0.50	0.46 ± 0.80	0.33 ± 0.82	1.21	0.25
Wind speed(km/hr)	10.9 ± 4.3	12.5 ± 5.7	1.71	0.091	10.9 ± 4.3	9.85 ± 2.8	1.44	0.15	12.5 ± 5.7	10.6 ± 3.6	1.56	0.025	11.7 ± 5.1	10.6 ± 3.6	1.92	0.067
Moon illuminated (%)	49.4 ± 34.9	62.9 ± 30.8	2.32	0.022	49.4 ± 34.9	45.9 ± 36.3	0.41	0.68	62.9 ± 30.8	50.0 ± 34.6	2.46	0.015	55.7 ± 33.6	50.0 ± 34.6	1.26	0.21

Table 2.—Categorical weather condition for different categories of days within the 5 years of the study in Northeastern Illinois. Results from chi-squared tests to compare occurrence of weather conditions between the different categories. Note that multiple females were seen digging with and with out oviposition on the same day and those values are repeated.

Categorical variable	Digging and oviposition (n=67)	Digging without oviposition (n=59)	χ^2	*p*	Digging and oviposition (n=67)	Inactivity during nesting duration (n=24)	χ^2	*p*	Digging without oviposition (n=59)	Inactivity during June (n=105)	χ^2	*p*	Nesting behavior (n=126)	Inactivity during June (n=105)	χ^2	*p*
Wind direction (%)																
N	11.94	5.085	5.563	0.135	11.94	41.67	14.32	0.002	5.085	40.95	29.025	<0.001	8.73	40.95	39.82	<0.001
E	22.38	11.86			22.38	25.00			11.86	11.42			17.46	11.42		
S	59.70	71.18			59.70	20.83			71.18	33.33			65.08	33.33		
W	5.97	11.86			5.97	12.50			11.86	14.28			8.73	14.28		
Moon phase: waxing gibbous to last quarter(%)	61.19	77.97	4.129	0.042	61.19	37.50	4.007	0.045	77.97	48.57	13.508	<0.001	69.05	48.57	9.9841	0.0016
Clear nights (starts at 1900hr) (%)	38.8	47.46	0.959	0.327	38.80	37.50	0.013	0.91	47.46	52.38	0.366	0.545	42.56	52.38	2.084	0.1488
Clear days(%)	35.82	35.59	0.001	0.979	35.82	12.50	4.605	0.032	35.59	39.04	0.708	0.661	35.71	39.04	0.2723	0.6018

Continuous variables were compared using an ANOVA to determine if the wind direction tends to bring different weather. Southern winds brought warmer temperatures when looking at digging without oviposition versus inactivity during June and nesting behavior versus inactivity during June (p=<0.001,Table 3). West and South winds correlated with lower average air pressure (*p*=0.001,Table 3). Wind direction does not correlate to the amount of precipitation (p=0.335,Table 3).

To create a guide for managers to predict when nesting activity would be most likely in a given season, the three most contributory weather conditions (mean temperature, moon phase, and average air pressure) were used to create a decision tree (Fig. 2). Inactivity will most likely occur when the mean temperature is less than 18.89 ºC or above that temperature and the moon phase is not in the brightest phases (Fig. 2). Nesting behavior is most likely to occur when the moon phase is in the brightest stage, mean temperature is above 23.33 ºC, and the air pressure is at or below 757.936 mmHg (Fig. 2).

Table 3.—Results from ANOVA(one-way comparison) that compare the wind direction to maximum temperature and precipitation over the month of June from 2013-2017. The mean is followed by the variance.

Wind direction	Maximum temperature (ºC)	Fisher pairwise comparison	*F*	*p*
N	20.83 ± 3.8 (n=50)	C	30.04	<0.001
E	23.33 ± 3.2 (n=24)	B		
S	26.99 ± 3.4 (n=57)	A		
W	26.78 ± 3.8 (n=19)	A		
Wind direction	**Precipitation (cm)**	**Fisher pairwise comparison**	***F***	***p***
N	0.393 ± 0.99 (n=50)	A	1.14	0.335
E	0.138 ± 0.34 (n=24)	A		
S	0.474 ± 0.86 (n=57)	A		
W	0.231 ± 0.56 (n=19)	A		
Wind direction	**Average air pressure (mmHg)**	**Fisher pairwise comparison**	***F***	***p***
N	760.58 ± 3.42 (n=50)	A	5.87	0.001
E	761.18 ± 2.72 (n=24)	A		
S	759.21 ± 3.07 (n=57)	B		
W	757.68 ± 3.63 (n=19)	B		

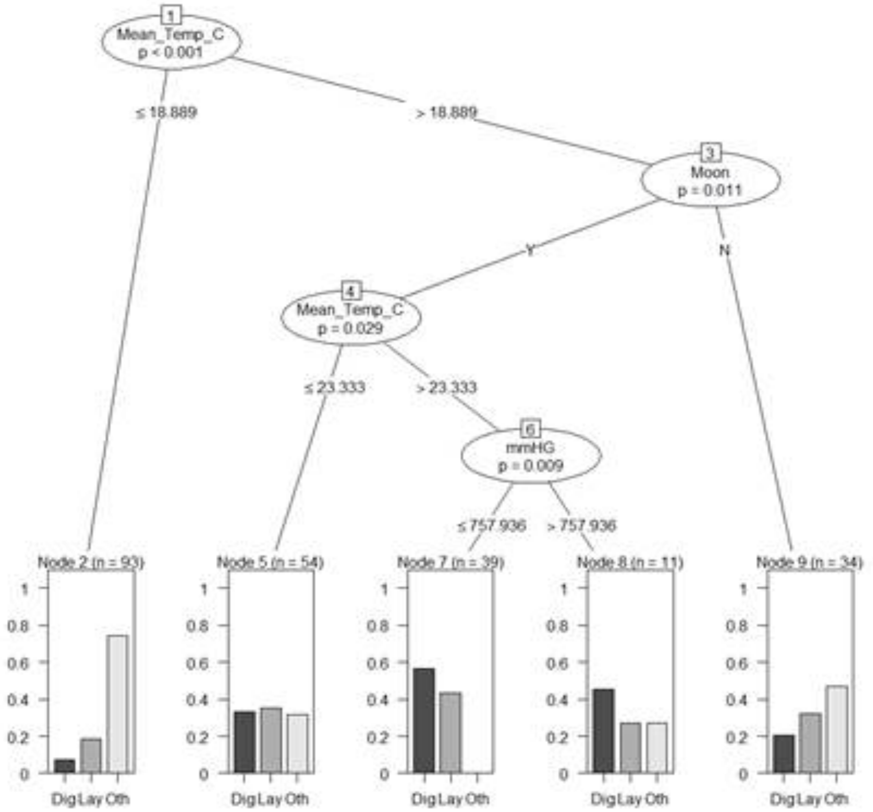

FIG. 2.— Decision tree using the three more significant data points, mean temperature (ºC), moon phase (waxing gibbous to last quarter), and average air pressure (mmHg). The graphs at the bottom show the likelihood of the 3 activity types: digging without oviposition ("dig"), digging with oviposition ("lay"), and inactive days in June ("oth").

DISCUSSION

In this study I observed that the Julian date of nesting in Blanding's Turtles tends to occur earlier in the year with warmer spring temperatures. Warmer spring temperatures may allow females to access food earlier in the year to support egg development and also allows them to have a warmer body temperature sooner than in cooler spring temperatures. Other reports have suggested just the mean temperature in April was correlated to the start of nesting season, but it is understood that warm days are important for the completion of egg production (Congdon et al. 1983; Tucker 1997). This pattern of warmer spring temperatures could be a result of global climate change, which would allow the females to nest earlier in their nesting season and have more assurance that there is enough time for development in the nest during the growing season for populations in the upper limits in their range (Walde et al. 2007; Schwanz and Janzen 2008).

The temperature was significantly higher on days that females were actively nesting versus the days with no nesting activity. Turtles are ectothermic, so having warmer ambient air temperatures throughout the day would make it easier for the females to use the built up heat to dig a nest in the cooler night and not to stay warm by hiding in vegetation or the water (Harding and Bloomer 1979; Congdon and Keinath 2006). The temperature on days when females were seen digging with and without oviposition was significantly different with higher temperatures on the days that digging without oviposition occurred. Warmer temperatures are necessary for the turtles to be active, but an upper temperature limit seems to exist during nesting season at which a female will retreat and not lay eggs. This could indicate Blanding's Turtles have a thermal zone for nesting that is lower then their critical thermal maximum that was found. Some females appeared to stay out of water during the day prior to nesting. This could have facilitated warmer body temperatures in the females and caused them to return to the water when they became too warm. The possibility of abandonment of a nest due to high temperatures could ensure survival of the female and her future offspring.

The amount of precipitation had no significance on the nesting activity of this population of turtles. It is thought that Blanding's Turtles nest on rainy nights because the rain softens the soil for digging and decrease olfactory cues left behind used by meso-predators to locate nest sites (Congdon et al. 2000; Bowen et al. 2005; Bowen and Janzen 2005). A study found that the olfactory cues do not effect nest survival and those cues don't disappear in the environment (Bowen and Janzen 2005). Another study suggested that meso-predators detect snapping turtle's (*Chelydra serpentina*) nests less by olfactory cues, but mostly by tactile cues that marked where the nests were (Oddie et al. 2015). This could mean that, for Blanding's Turtles, rain is not necessary for nesting but helpful in ensuring that upon coving the nest the substrate is the same as the surrounding area. Because the amount of rain is not a direct cue for females, the soil moisture or an indication that rain is coming soon could be the cue to help reduce predation by meso-predators.

For all comparisons, the average air pressure is significantly lower for nesting behaviors and ovipositoning. In a study, the first nesting attempts of Western Pond Turtles (*Emys marmorata)* were found to be driven by maximum temperature and low air pressure (St. John 2015). Blanding's Turtles may have a similar nesting relationship to lower air pressure as the Western Pond Turtle, since air pressure seems to be a Blanding's Turtle nesting trigger. Air pressure tends to be related to rainfall, the lower the pressure the more likely precipitation will follow and the higher the pressure the less likely there will be precipitation (Chapman 1916). Females may react to the cue of air pressure and not rainfall because it can indicate the likelihood of precipitation in the near future to help seal the nest and minimize predation pressures.

Digging without oviposition has a significantly higher average dew point then the inactive days in June. Dew point increases as temperature increased, and the temperature when digging with oviposition occurred was on average higher than during other activity types. Dew point is also positively correlated to increasing relative humidity at any temperature, meaning the higher the dew point the more moisture in the air (Lawrence 2005). With an increase of humidity, the soil moisture is not likely to evaporate, which can lead to the soil moisture remaining the same for surrounding soil. In a study with Wood Turtles (*Glyptemys insculpta)*, it was found that while nesting, Wood Turtle females preferred the same moisture content of the soil to nest which suggests they rely on humidity for nesting days (Hughes et al. 2009). Blanding's Turtles might be choosing nesting days with dew points that could stabilize the soil moisture. Although humidity was not significant in this study, the relationship between humidity and dew point might be a signal to identify an expected nest site and time.

The percent of moon illuminated did not differ significantly between digging with and without oviposition and inactive days during June. Digging without oviposition occurred when the moon was at a higher percent moon illuminated than digging with oviposition. For all comparisons, day with activity had a greater percent of days with the moon in the brightest part of the lunar phases (Waxing Gibbous to Last Quarter). Oviposition is significantly lower in number of individuals nesting during the higher percent of moon illuminated and the days with the brightest part of the lunar phase. There is most likely a range of moon brightness that is optimal for females to nest. For Leatherback Sea Turtles (*Dermochelys coriacea*), along with species of amphibians and crabs, nesting events are affected by the lunar phase and females are seen nesting during the later moon stages (Watson et al. 2015). Blanding's Turtles use their sight while digging to watch for predators-even humans known to occasionally scare them off their nest (Synder 1921; Congdon et al. 1983; Frye et al. 2017). With more light, females may be more easily detect predators and be more easily scared off their nest. Another possibility is that when the moon is brighter, predators are out more often and it is more likely for them to abandon their nest because a predator knows where a nest is, and is more likely to predate the nest (Oddie et al. 2015).

Wind direction is significantly different between active and inactive days of nesting behavior, with nesting behavior days more likely to have south winds. West and South winds are significantly correlated to higher maximum temperatures for the day and lower average air pressure, which both had significantly more nesting activity on those days. Wind direction had no correlation to amount of precipitation, so the females are most likely not responding to the wind direction because of the chance of precipitation. Wind direction itself is unlikely to have an effect on nesting, but the weather conditions that the wind brings are more likely to have an effect on when an individual chooses to nest.

The decision tree created can help to understand how multiple weather conditions influence the nesting habits of female Blanding's Turtles. A combination of warm mean temperatures, brighter moon phase and low average air pressure indicates that nesting behavior will occur. Females seem to use more than one weather condition as a cue for when to nest. Using multiple weather conditions allows females to have more opportunities to nest, but still maintain optimal conditions for nesting and potentially better nest success. This tree can be used by biologists to help predict the nights that females will be actively nesting. These predictions can help to increase efficiency in finding nesting females and potentially being able to document more adult females and their nests. With more known nest locations, protection of the nest can occur through nest cages or eggs can be harvested for captive incubation. Being able to predict the likelihood of when females will nest can help to support populations in becoming a self-sustaining viable population.

CONCLUSION

Female Blanding's Turtles most likely respond to environmental cues in determining when and where to nest. In our study, warmer temperatures, lower average air pressure, and brighter moon phase were determined to be the biggest indicators of nesting. Wind direction also appears to be important as it is correlated with warmer temperatures and lower average air pressure, which may be a more influential cue to females. Females are most likely using many conditions as a cue for nesting, and there may be differences between populations. Knowing this information for a given population can help researchers understand when to deploy their resources to search for nesting females in order to further understand document nests, determine success rates and allows for protections to be implemented to increase nest success.

Climate change is likely to have an effect on Blanding's Turtles because of the changes in temperature and moisture. The warmer temperatures earlier in the year can allow females to nest sooner, and in return nest success benefits from a longer summer, which can be advantageous for successful egg development (Schwanz and Janzen 2008). This might also cause a bias towards female hatchlings because when the soil is warmer, females are more likely to develop (Janzen 1994; Schwanz and Janzen 2008). This bias may help to support Blanding's Turtle populations and reproductive success, by offsetting the decline due to road mortality, as females are the most susceptible (Gibbs and Steen 2005). While climate change is typically regarded as likely to have an aggregate negative effect on wildlife, for Blanding's Turtles at the northern edge of their range, its effects in the next 100 years could be positive.

This is just the beginning of understanding what causes an individual Blanding's Turtle to nest. More research needs to be done to understand the difference between the environmental and biological cues to nesting. Biological cues could be genetically passed down from their mother or when an individual will oviposit may be determined by size of the female or circannual cycle. Along with understanding when a female will nest, more understanding is needed for why females are choosing their nest sites and the influence of environmental and biological conditions on nest site selection. A deeper understanding of when and where Blanding's Turtles nest can help scientists and conservationists understand populations in a way the might not be possible just by trapping or random nesting searches.

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LITERATURE CITED

Bleakney 1963[Notes on the distribution and life history of turtles in Nova Scotia Can. Field Nat]

Bowen, K. D., & Janzen, F. J. (2005). Rainfall and Depredation of Nests of the Painted Turtle, *Chrysemys picta*. *Journal of Herpetology,39*(4), 649-652. doi:10.1670/34-05n.1

Bowen, K. D., Spencer, R., & Janzen, F. J. (2005). A comparative study of environmental factors that affect nesting in Australian and North American freshwater turtles. *Journal of Zoology,267*(04), 397-404. doi:10.1017/s0952836905007533

Brown 1927 [A Blanding's turtle lays its eggs. Can. Field Nat.],

Chapman, L. T. (1916). The relation between atmospheric pressure and rainfall at Kew and Valencia observatories. *Quarterly Journal of the Royal Meteorological Society,42*(180), 289-299. doi:10.1002/qj.49704218009

Congdon, J. D., Tinkle, D. W., Breitenbach, G. L., & Van, R. C. (1983). Nesting Ecology and Hatching Success in the Turtle *Emydoidea blandingii*. *Herpetologica ,39*(4), 417-429. Retrieved July 7, 2017, from http://www.jstor.org/stable/389253

Congdon, J., Dunham, A., & R. C. Van Loben Sels. (1993). Delayed Sexual Maturity and Demographics of Blanding's Turtles (Emydoidea blandingii): Implications for Conservation and Management of Long-Lived Organisms. *Conservation Biology,7*(4), 826-833.

Congdon, J. D., Nagle, R. D., Kinney, O. M., Osenioski, M., Avery, H. W., Van Loben Sels, R. C., & Tinkle, D. W. (2000). Nesting Ecology and Embryo Mortality: Implications for Hatchling Success and Demography of Blanding's Turtles (*Emydoidea blandingii*). *Chelonian Conservation and Biology ,3*(4), 569-579.

Congdon D., J. & Keinath A., D. (2006) Blanding's Turtle (*Emydoidea blandingii*): a technical conservation assessment. doi:10.2307/1437255

Frye, A., Hardy, K., Hedrick, A. R., & Iverson, J. B. (2017). Factors Affecting Nesting Times in the Painted Turtle *Chrysemys picta* in Nebraska. *Chelonian Conservation and Biology,16*(1), 44-51. doi:10.2744/ccb-1208.1

Gibbs, J. P., & Steen, D. A. (2005). Trends in Sex Ratios of Turtles in the United States: Implications of Road Mortality. *Conservation Biology,19*(2), 552-556. doi:10.1111/j.1523-1739.2005.000155.x

Harding, J. H., & Bloomer, T. J. (1979). The Wood turtle, *Clemmys insculpta*… A Natural History. *HERP,15*(1).

Hothorn, T., Hornik, K., & Zeileis, A. (2006). Unbiased Recursive Partitioning: A Conditional Inference Framework. *Journal of Computational and Graphical Statistics,15*(3), 651-674. doi:10.1198/106186006x133933

Hughes, G. N., Greaves, W. F., & Litzgus, J. D. (2009). Nest-site selection by wood turtles (Glyptemys insculpta) in a thermally limited environment. *Northeastern Naturalist*, *16*(3), 321-338.

Illinois Natural History Survey. (2016). Conservation guidance for Blanding's Turtle (*Emydoidea blandingii*). Report prepared for the Illinois Department of Natural Resources, Division of Natural Heritage.

Janzen, F. L. (1994). Climate Change and Temperature-Dependent Sex Determination in Reptiles. *Proceedings of the National Academy of Sciences of the United States of America,91*(16), 7487-7490. Retrieved from http://www.jstor.org/stable/2365309

Lawrence, M. (2005). The relationship between relative humidity and the dewpoint temperature in moist air: A simple conversion and applications. *Bulletin Of The American Meteorological Society*, *86*(2), 225-233. doi:10.1175/BAMS-86-2-225

Millar, C. S., & Blouin-Demers, G. (2012). Habitat suitability modeling for species at risk is sensitive to algorithm and scale: A case study of Blanding's turtle, Emydoidea blandingii, in Ontario, Canada. *Journal for Nature Conservation,20*(1), 18-29. doi:10.1016/j.jnc.2011.07.004

Mui, A., Edge, C., Paterson, J., Caverhill, B., Johnson, B., Litzgus, J., & He, Y. (2016). Nesting sites in agricultural landscapes may reduce the reproductive success of populations of Blanding's Turtles (*Emydoidea blandingii*). *Canadian Journal of Zoology,94*(1), 61-67. doi:10.1139/cjz-2015-0154

Oddie, M. A., Coombes, S. M., & Davy, C. M. (2015). Investigation of cues used by predators to detect Snapping Turtle (*Chelydra serpentina*) nests. *Canadian Journal of Zoology,93*(4), 299-305. doi:10.1139/cjz-2014-0264

Quinn, V. S., & Graves, B. M. (1998). Home Pond Discrimination Using Chemical Cues in *Chrysemys picta*. *Journal of Herpetology,32*(3), 457-461. doi:10.2307/1565467

Rowe, J., & Moll, E. (1991). A Radiotelemetric Study of Activity and Movements of the Blanding's Turtle (*Emydoidea blandingi*) in Northeastern Illinois. *Journal of Herpetology, 25*(2), 178-185. doi:10.2307/1564646

Schwanz, L. E., & Janzen, F. J. (2008). Climate Change and Temperature-Dependent Sex Determination: Can Individual Plasticity in Nesting Phenology Prevent Extreme Sex Ratios? . *Physiological and Biochemical Zoology,81*(6), 826-834. doi:10.1086/590220

Standing, K. L., Herman, T. B., & Morrison, I. P. (1999). Nesting ecology of Blandings turtle (*Emydoidea blandingii*) in Nova Scotia, the northeastern limit of the species range. *Canadian Journal of Zoology,77*(10), 1609-1614. doi:10.1139/cjz-77-10-1609

St. John, W. A. (2015). *Drivers of non-random nest-site selection in an oviparous vertebrate*(Unpublished master's thesis). Sonoma State University. Retrieved from http://sonoma-dspace.calstate.edu/handle/10211.3/173734

Synder 1921 [Some observations on the Blanding's turtle Can. Field. Nat.]

Tucker, J. K., Jeffords, M. R., Rice, T. E., & Warwick, C. (1997). Natural history notes on nesting, nests, and hatchling emergence in the red-eared slider turtle, *Trachemys scripta elegans*, in west-central Illinois / John K. Tucker. doi:10.5962/bhl.title.15181

Walde, A. D., Roger Bider, J., Masse, D., Saumure, R. A., & Titman, R. D. (2007). Nesting Ecology and Hatching Success of the Wood Turtle, *Glyptemys insculpta*, in Quebec. *Herpetological Conservation and Biology ,2*(1), 49-60.

Watson, M. K., Stewart, K., Norton, T. M., & Mitchell, M. A. (2015). Evaluating Environmental and Climatic Influences on Nesting in Leatherback Sea Turtles (*Dermochelys coriacea*) in St. Kitts, West Indies. *Journal of Herpetological Medicine and Surgery,25*, 122-127. doi:10.5818/15-01-035.1

Appendix I

FEMALES may be choosing more than the day that they nest. The nest site could be an important choice for the female to make because it could affect nest success. Many studies have thought that the distance from the nearest wetland is part of the deciding factor of where the nest site is located (Wilson 1998; Standing et al. 1999; Mui et al. 2016). Well-drained soils with little vegetation have also been found to increase the chance of hatching (Bleakney 1963; Wilson 1998; Congdon et al. 2000; Mui et al 2016). This is just the start of understanding nest site selection by female Blanding's Turtles and the possibility for scientist to predict where a female will nest.

METHODS AND MATERIALS

I used nesting and digging locations from a longer-term study region at Spring Bluff Nature Preserve and Chiwaukee Prairie State Natural Area to understand where the females are choosing to nest. I compared locations of nesting behavior to random points within this region for the type of nesting site (artificial or natural) and approximate distance to water using Google Earth Pro. If the point was on a structure or landscape heavily altered by humans it is considered to be artificial. These sites included farm fields, railroad tracks and embankments, and mowed grass paths or lawns.

RESULTS

I got the approximate distance to the nearest water form observed nesting locations ($\bar{x}$ =71.98, SD= 52.26, n=91, FIG. 3) and random points within the active region ($\bar{x}$ = 71.20, SD=59.48, n=70). There is not significant difference between the distances to water for nesting and random sites (p=0.931).

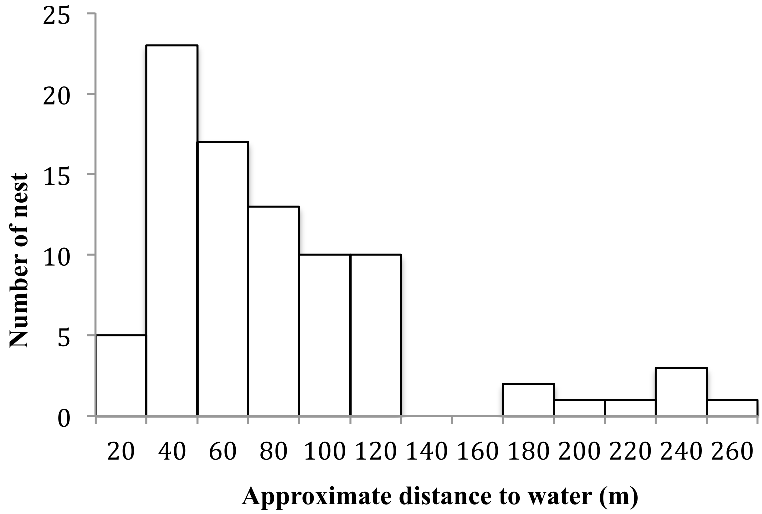

FIG.3.—Histogram of the approximate distance from a *E. blandingii* nest location to the nearest water body over the course of 5 years ($\bar{x}$ = 71.98 ± 25.26, n=91).

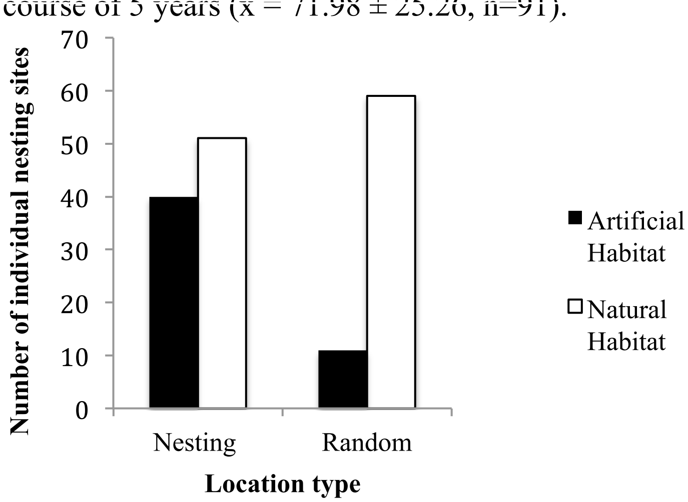

FIG.4.—The number of *E. blandingii* nest locations and random possible nest locations in two different habitat types. Artificial habitat is defined as any human altered and managed land like railroad embankments, farm fields, mowed grass yards and paths. Natural habitat it defined as unaltered by human activity.

The habitat available for nesting versus where females exhibited nesting behavior was significantly different (*p*= <0.001,FIG. 4). This Blanding's Turtle population is more likely to select artificial habitats for nesting over the available land cover.

DISCUSSION

Many papers have stated that females often choose to nest close to the wetlands for self-preservation (Wilson 1998; Standing et al. 1999; Mui et al. 2016). Females in our study did not specifically choose to nest close to water, or else the distance to water from random points in the active region would have been significantly different than nesting points. This could be because females are choosing nesting locations on other conditions like soil type for easier digging, soil moister to help make sure the eggs are not dehydrated, elevation to help decrease flooding risk to the nest, and vegetation that can either absorb the extra moisture or canopy that can cool the soil that could cause different sex ratios of the hatchlings (Wilson 1998; Congdon et al. 2000; Mui et al 2016). The vegetation between the nest site and the closest wetland could also have an effect because cover may be necessary to keep females from overheating during nesting forays and may protect hatchlings when they move to the water.

Habitat type, natural or artificial, is significantly different between the nesting sites and random types. Nest sites tend to be more likely on artificial habitats then the random points. Railroad banks are the most-used artificial habitat for nesting. Elevation of the banks or soil at the sites of nesting could have an affect (Wilson 1998). Also the railroad bank is kept clean of vegetation that might shade the nest or take the moisture that the eggs need to be hydrated (Wilson 1998; Congdon et al. 2000; Mui et al. 2016).

CONCLUSION

Understanding Blanding's Turtle nest-site selection is more complex than what has been found in this study. Further research should address whether females are individually choosing where they nest or if nest-site fidelity plays a role in the location of subsequent nesting attempts. Long-term studies can be done to look at the possibility for females passing the nest location down to their offspring or to find common location characteristics that offspring inherit form their mother. Sea turtles most often return to the same beach as they were born. This might be the case with Blanding's Turtles as well. More studies should be done to help answer these questions.

LITERATURE CITED

Wilson, D. S. (1998). Nest-Site Selection: Microhabitat Variation and Its Effects on the Survival of Turtle Embryos. *Ecology,79*(6), 1884-1892. doi:10.2307/176696