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Short Communication

Seasonal pattern of basking activity in *Nerodia sipedon* (Serpentes: Colubridae) along a western Michigan lakeshore, USA

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The Common Watersnake, *Nerodia sipedon* (Linnaeus, 1758), typically basks close to the water's edge (Laurent and Kingsbury 2003, Burger *et al*. 2004, Stanford *et al*. 2010). In addition, *Nerodia* spp. often bask on structures overhanging the water (Hebrard and Mushinsky 1978), and *N. sipedon* readily use anthropogenic structures in urban area (Pattishall and Cundall 2009).

Environmental conditions can influence basking and activity in *N. sipedon*. *Nerodia sipedon* basked more frequently when there was little cloud cover (i.e., when it was sunnier) (Burger *et al*. 2004). Burger *et al*. (2004) found that *N. sipedon* basked when air temperatures were between 12 and 30°C and when water temperature was > 15°C. Observed diel variation in activity by *N. sipedon,* with basking occurring primarily early in the morning and late in the afternoon (Robertson and Weatherhead 1992, Ernst *et al*. 2012) with aquatic activity in the middle of the day (Tiebout and Cary 1987), may reflect the diel pattern of environmental conditions. For example, *Nerodia fasciata* (Linnaeus, 1766) and *N. taxispilota* (Holbrook, 1838) enter the water when the water temperature is greater than air temperature and aerially bask or leave the water when air temperature is higher than water temperature (Osgood 1970, Robertson and Weatherhead 1992).

Previous studies examining basking and activity of *N. sipedon* have been conducted in natural, relatively undisturbed marsh habitat (Robertson and Weatherhead 1992), in a national wildlife refuge (Ernst *et al.* 2012), and a canal in an urbanized area (Burger *et al*. 2004). Thus, these studies do not allow for a direct comparison in basking activity between habitats with varying levels of human influence in a single lake. Pattishall and Cundall (2008, 2009) found that *N. sipedon* make use of urban areas of a stream, and make extensive use of anthropogenic structures to bask but their movement and site fidelity differs between areas of the stream that vary in human influence.

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We examined the numbers of *N. sipedon* observed along the shore of a lake in suburban Kalamazoo County, Michigan, USA that has habitats ranging from basically natural to heavily human influenced. In particular, we evaluated the potential role of date, time of day, and environmental conditions (air temperature, wind speed, and sky conditions), as well as extent of human influence, on the number of *N. sipedon* observed. Our study therefore provides information on how human influence within a single lake may influence the basking activity of *N. sipedon*.

As part of a study of turtle basking behavior (Hoinville and Smith, unpubl. data), we established 26 survey stations every 100 m along the perimeter of Lake Hill'n Brook and Howard Lake (Figure 1) in Kalamazoo County, Michigan, USA (42.246226, -85.632203). Stations were used to facilitate the checking of the entire shoreline by a single observer in a concise time frame. Each survey station was an approximately 6 m stretch of shoreline. When observing each survey station, the observer was usually at least 10 m and often > 15 m from shore. Making observations at these distances from the shore appeared to minimize any disturbance of the snakes. These survey stations represented the range of available habitats and included sites with a variety of human influence (Figure 2). The majority of stations (16 of 26; 61.5%) were along sections of the shore where the shoreline

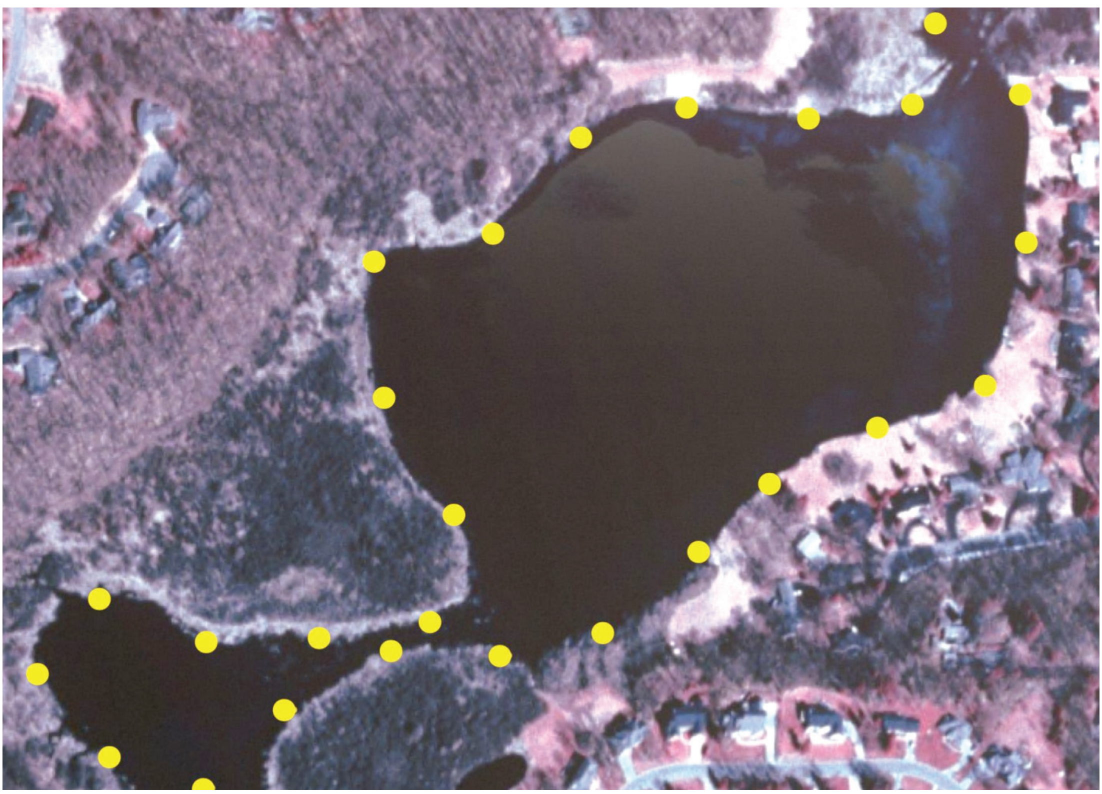

Figure 1. Map of survey stations (yellow dots) along the shoreline of Lake Hill'n Brook and Howard Lake in Kalamazoo County, Michigan, USA. Base map credit: United States Department of Agriculture, Natural Resources Conservation Service, published 20 May 2002.

Figure 2. Photographs of representative survey stations with differing levels of human influences (**A**: Low, **B**: Intermediate, **C**: High) along the shores of Lake Hill'n Brook and Howard Lake in Kalamazoo County, Michigan, USA. Photos: EJH.

was relatively natural, with at least 15 m of marsh, swamp, or forest separating the shore from any human influence (Figure 2A). Five of the 26 survey stations (19.2%) had intermediate levels of human influence, where the shoreline was natural but the station was adjacent to or near artificial habitats (e.g., lawn, artificial beach) (Figure 2B). The six remaining stations (19.2%) were along shoreline that had high level of human influence, where the shoreline was artificially built up with wooden railroad tie seawalls, artificial rock substrate, or metal seawalls and with lawns extending right up to the water (Figure 2C).

From 18 May to 17 July 2020, one of us (EJH) conducted surveys on 40 d (i.e., most weekdays unless limited by weather) and counted the number of *N. sipedon* basking at each station from a canoe. We assumed *N. sipedon* were basking since they were in locations and postures suggesting basking (see Hebrard and Mushinsky 1978, Laurent and Kingsbury 2003, Burger *et al.* 2004, Stanford *et al.* 2010). We began surveys four times a day: 09:00 h (N = 20), 12:00 h

(N = 33), 15:00 h (N = 37), and 19:00 h (N = 32). Due to safety considerations, we did not conduct surveys during high winds or storms. At the start of each survey, we recorded air temperature, wind speed, and sky conditions [sunny (sunny and partly sunny) or cloudy (cloudy or mostly cloudy)]. We did not record snakes observed outside the survey stations.

We used generalized linear models (binomial distribution, logit link) to examine the effects of date, date^2, time of day (as a categorical variable), air temperature, wind speed, and sky conditions on the total number of *N. sipedon* observed basking during a survey (i.e., number of snakes observed pooled across all survey stations) for each survey. We compared candidate models (see Appendix I for all candidate models examined) using AICc to determine the best models. In addition, we used a chi-square test to compare the observed number of snake observations made among the three levels of human influence relative to the number expected if snakes were using the stations at random with respect to the level of human influence. We used JMP Pro 15.2 (SAS Institute, Cary, NC) for the statistical analyses.

Over the course of the study we made a total of 38 observations of individual *N. sipedon,* with a range of 0–5 in any given survey, with snakes observed on 14 of the 40 d (35%) surveys were conducted. We provide the five best overall models in Table 1. The best overall model included only date and time of day. Indeed, date and time of day appeared in all five of the best models. Date^2 and air temperature appeared in two of the five best models. Wind speed appeared in one of the best models. In general, the greatest numbers of *N. sipedon* observed were found early in the study period from 17 May to 8 June, followed by a period of several weeks when no snakes were observed from 18 June to 17 July (Figure 3A). During the day, the greatest number of *N. sipedon* observed was in the morning at 09:00 h, with very few individuals observed basking at 19:00 h (Figure 3B).

We observed *N. sipedon* at the relatively natural survey stations much more than they would be expected by chance, and at stations with intermediate or high levels of human influence much less than by chance (Natural: 35 observed, 23.4 expected; Intermediate: 3 observed, 7.3 expected; High: 0 observed, 7.3 expected; χ^2_2 = 15.58, p = 0.0004).

The most dramatic result of our observations is the strong degree to which *N. sipedon* used the most natural shoreline habitat stations and the apparent avoidance of shoreline with even intermediate levels of human influence. In contrast, Pattishall and Cundall (2009) found *N. sipedon* used a wide variety of anthropogenic structures, even using urban areas of a stream more than natural areas. Burger *et al*. (2004) found that *N. sipedon* in an urban canal quickly entered the water when approached by humans.

Our observations on the daily pattern of *N. sipedon* activity are similar to those from other

Table 1. The five best models from the candidate generalized linear models examining the number of *Nerodia sipedon* observed basking during individual surveys along the shores of Lake Hill'n Brook and Howard Lake in Kalamazoo County, Michigan, USA.

Model	AICc	DAICc
Date + Time	46.375	-
Date + Time + Air	47.266	0.891
Date + Date^2 + Time	47.585	1.211
Date + Date^2 + Time + Air	47.757	1.382
Date + Time + WS	48.188	1.813

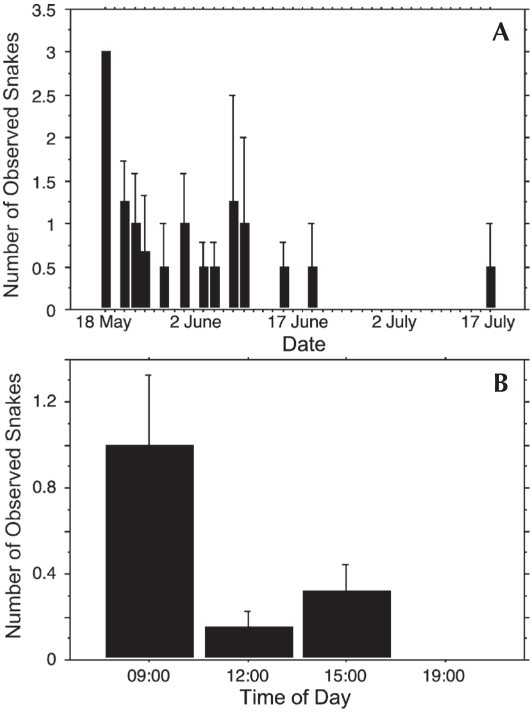

Figure 3. Mean ± SE number of *Nerodia sipedon* observed along the shores of Lake Hill'n Brook and Howard Lake in Kalamazoo County, Michigan, USA (**A**) each day during the study period, and (**B**) at each time of the day.

locations, with basking being most frequently observed early in the morning (e.g., Robertson and Weatherhead 1992, Ernst *et al*. 2012). Our results are also consistent with the observation that *N. sipedon* tend to shift to aquatic activity in the middle of the day (Tiebout and Cary 1987). This pattern is likely related to thermoregulation in *N. sipedon,* whereby body temperatures increased in the morning followed by constant temperatures for most of the day and declined in the evening (Brown and Weatherhead 2000).

We observed a peak in basking from late May to early June. This is slightly earlier than the observed seasonal activity of *N. sipedon* in Pennsylvania and Iowa that was highest in June and lasted from May to September (Klimstra 1958, Hughes *et al*. 2018). Meshaka *et al*. (2008) found *N. sipedon* under cover boards in northeastern Ohio most often in May and August. The observed seasonal pattern of basking activity by *N. sipedon* in our study may again reflect thermoregulatory pressures or opportunities. As the summer progresses, water temperatures likely increase, thereby potentially increasing the use of aquatic habitats relative to basking habitats (see Osgood 1970, Robertson and Weatherhead 1992, Burger *et al*. 2004). In addition, the higher numbers of observations in May and early June may be related to greater activity of *N. sipedon* during the breeding season, which typically occurs in May and June over much of its range (Bauman and Metter 1977, Mushinsky 1979, Aldridge 1982, Weatherhead *et al*. 1995).

Our results are consistent with Stevenson (1985) identifying diel and seasonal activity patterns as the most important behavioral mechanisms of body temperature regulation in terrestrial ectotherms. However, the presence of air temperature and wind speed in at least one of the five best models indicates environmental parameters may also be playing a role and may be indirectly included in both the time of day and day of the year variables. The model results emphasize the likely importance of thermo-regulation driving the patterns of basking in *Nerodia sipedon* that we observed.

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Appendix I. *Candidate General Linear Models (Binomial distribution, Logit link) for the number of* Nerodia sipedon *observed along the shores of Lake Hill 'n Brook and Howard Lake in Kalamazoo County, Michigan, USA. Models are given in order of AICc. Date = day of year, Time = time of day, Air = air temperature, Sky = sky condition, WS = wind speed.*

Model	**AICc**	**DAICc**
Date + Time	46.375	-
Date + Time + Air	47.266	0.891
Date + $Date^2$ + Time	47.586	1.211
Date + $Date^2$ + Time + Air	47.757	1.382
Date + Time + WS	48.188	1.813
Date + Time + Sky	48.518	2.143
Date + Time + Air + WS	49.155	2.780
Date + $Date^2$ + Time + WS	49.284	2.909
Date + Time + Air + Sky	49.289	2.914
Date + $Date^2$ + Time + Air + WS	49.411	3.036
Date + $Date^2$ + Time + Air + Sky	49.569	3.194
Date + $Date^2$ + Time + Sky	49.792	3.417
Date + Time + Air + WS + Sky	51.226	4.851
Date + $Date^2$ + Time + Air + WS + Sky	51.288	4.913
Date + $Date^2$ + Air	52.313	5.928
Date + Air	54.934	8.559
Date	55.704	9.329
Date + $Date^2$	55.770	9.395
Date + Air + Sky	56.119	9.744
Date + Air + WS	56.718	10.343
Time + Air + WS	56.888	10.513
Date + $Date^2$ + WS	57.109	10.734
Date + WS	57.206	10.831
Air	57.314	10.939
Time + Air	57.482	11.107
Date + Sky	57.637	11.262
Date + $Date^2$ + Sky	57.867	11.492
Date + Air + WS + Sky	57.896	11.521
Air + WS	57.945	11.570
Time + Air + WS + Sky	58.931	12.556
Air + Sky	59.084	12.709
Date + WS + Sky	59.111	12.736

Appendix I. *Continued.*

Model	AICc	DAICc
Air + WS + Sky	59.458	13.083
Time + Air + Sky	59.514	13.139
Time + WS	59.628	13.253
WS	62.104	15.729
Time	62.944	16.569
WS + Sky	64.138	17.763
Time + Sky	65.118	18.743
Sky	66.570	20.195