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IMPACTS OF HUMAN RECREATION AND HYDROELECTRIC FLOW REGIME ON BASKING BEHAVIOR OF NORTHERN MAP TURTLES, *GRAPTEMYS GEOGRAPHICA*.

by

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THESIS APPROVAL PAGE

This is to certify that the thesis prepared by Kaite Anderson

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ABSTRACT

Impacts of human recreation and hydroelectric flow regime on basking behavior of Northern Map Turtles, *Graptemys geographica*.

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Northern Map turtles, *Graptemys geographica*, are state endangered in Maryland and are found only on the Lower Susquehanna River and its tributaries. Human recreation and water level fluctuations from the Conowingo Dam potentially limit basking behavior in this population. Turtles rely on basking to thermoregulate; decreased basking activity can potentially decrease population viability. I quantified the effects of 1) recreational human disturbance and 2) rising water from the hydroelectric dam on basking behavior. While motor-powered boats were often ignored, turtles were most often disturbed by slow-moving vessels like kayaks. Habitat use changed with increasing water levels; the interaction between dam flow and tide level had the greatest effect on basking behavior. Basking activity typically decreased as available habitat decreased. These disturbances do restrict basking behavior and require immediate mitigation. Artificial basking platforms and seasonal boating regulations should be implemented. Preparations for testing artificial basking platforms have already begun.

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Introduction

The widespread decline of turtles is a major concern to conservation biologists worldwide (Gibbons et al., 2000; Moll and Moll, 2004). Such declines are attributed to a variety of factors, including shoreline and land development, pollution, invasive competitors, over-harvesting, increase in human-subsidized predators, and habitat loss (Ernst and Barbour, 1989; Pough et al., 1998; Moll and Moll, 2004). Habitat loss and modification are two leading causes of decline for riverine turtles in particular (Tear et al., 2005; Carriere, 2007; Richards-Dimitrie, 2011). Riverine turtles require the use of multiple habitat types in order to locate viable food sources, find nesting sites, seek mates, hibernate, bask, and find refuge from predators, adverse conditions, etc. (Moll and Moll, 2004; Carriere, 2007). Because turtles are long-lived organisms with late maturation, limited access to any of these habitat types can potentially lead to population declines (Moll and Moll, 2004; Moore and Seigel, 2006). This delayed maturation also makes it hard to recognize population declines in real-time, which often results in delayed or misguided conservation efforts (Congdon et al., 1993; Moore and Seigel, 2006).

Dams are a classic example of habitat modification (McCartney, 2009; Bennett et al., 2010). Sixty percent of the world's rivers are fragmented by dams for power generation, irrigation, transportation, etc. (Poff et al., 1997; Graf, 1999; McCartney, 2009), and virtually all of the large rivers in the United States have been fragmented by dams to some degree (Graf, 1999). Dams can alter the natural thermal quality of a river, change the flow/flood regime, increase sedimentation during flood events, and limit biodiversity (Poff et al., 1997; McCartney, 2009). Not only do these dams fragment populations, dividing the amount of available habitat, they further limit this diminished habitat by altering the natural flow regime (Poff et al. 1997; Lylte and Poff, 2004; Bennett et al., 2010; Richards-Dimitrie, 2011).

The natural flow regime of a river is the key to maintaining the biodiversity and ecological integrity of the system (Poff et al., 1997; Bunn and Arthington, 2002). A river's natural flow can vary on multiple time scales and is determined by magnitude of discharge, frequency of flow events, the duration of the flow condition, timing of flow, and the flashiness (i.e. how rapidly the system changes) with which the flow changes in magnitude (Poff et al., 1997; Lytle and Poff, 2004). Unaltered or undammed rivers typically experience seasonal fluctuations in magnitude, providing a fairly predictable flood schedule with a predictable flood duration (Graf, 2006). These rivers are not subject to variability in timing or flashiness on a short time scale as are regulated rivers (Graf, 1999, 2006; McCartney, 2009). Although minimum and maximum discharge for natural flow in rivers varies from region to region, Graf (2006) showed that on a long-term scale, unregulated rivers experience higher high flows and lower low flows than regulated rivers. Even though impounded rivers may not experience as high a flood peak, their mean base flow tends to be higher than in unregulated rivers. Regulated rivers also exhibit a reduction in floodplain size, which simplifies the landscape and limits available habitat (Bunn and Arthington, 2002; Graf, 2006). This is particularly detrimental for riverine turtles, as these systems lack the presence of sandbars which are preferred for nesting (Bodie et al., 2000; Vogt, 1980a; Moll and Moll, 2004).

However, Moll and Moll (2004) warned that there is a difference between river turtles and turtles that live in rivers; distinguishing this is key when determining important habitat elements for a particular species. The authors pointed out that there are two distinct types of large rivers that provide habitat for riverine turtles: the reservoir river and the flood river. Reservoir rivers are typically stable throughout the year due to even rainfall among months or contain marginal water bodies that release water into the river at a steady rate over time. These rivers rarely overtop their banks and provide excellent habitat for generalist species as the environment remains fairly constant. Flood rivers, on the other hand, are subject to seasonal changes in precipitation and often experience overflowing of the main channel. These systems are much more dynamic, with an assortment of associated habitats such as oxbows, point bars, ephemeral wetlands, and meanders. Flood rivers and their respective habitats are home to a combination of generalist and specialist species. Obst (1986) categorized river turtles into four main groups: (1) semi-terrestrial, weak swimmers found in river-bank regions; (2) good swimmers that are found in river-bank regions and feed exclusively in the water, leaving occasionally to nest or bask; (3) completely aquatic species that feed exclusively in the water and rarely bask; (4) turtles of the open water that cover large aquatic home ranges, only leaving the river nest. It is clear that the definition of "river turtle" is complicated and is determined by many factors. It is important, then, to focus on species that are river specialists - those that inhabit the main channel of the river and its immediately adjacent tributaries (Moll and Moll, 2004).

In order to mitigate the threats of habitat loss and modification via dams, it is important to understand what drives habitat selection in river turtles. This allows us to conserve or reproduce those habitat elements that are most important to a riverine turtle (Heard et al., 2004). Selection of a particular habitat type in the river depends on whether a resource is used above, below, or in proportion to its availability (Johnson, 1980; Compton et al., 2002). It is important to look at habitat selection on multiple spatial scales - from dispersion to home range size, to use of habitat components, to selection of individual resource items (Luck, 2002; McLoughlin et al., 2002; Morin et al., 2005). Patterns observed at one scale are not necessarily observed at another scale, making it crucial to look at the patterns or synergy existing between multiple scales before conclusions can be drawn (Morin et al., 2005).

The objective of my study was to understand what factors affect basking habitat selection in an isolated population of Northern Map Turtles, *Graptemys geographica.* I focused on basking habitat selection at the local scale and the habitat component level (Morin et al., 2005), as general Northern Map Turtle habitat use at the landscape scale was previously documented by Richards- Dimitrie (2011).

Adequate basking habitat is crucial to aquatic turtles. As ectotherms, turtles cannot internally regulate their body temperature; basking behavior allows them to successfully complete virtually all biological processes associated with body temperature (Bulte and Blouin-Demers, 2010). Thermoregulation via basking contributes to foraging rate, digestion rate, mating behavior, predator avoidance, prevention of skin and shell parasites, and Vitamin D synthesis (Shealy, 1976; Crawford, 1983; Schwarzkopf and Brooks, 1985; Lindeman, 1999; Ben-Ezra et al., 2008). Aquatic turtles are known to bask on the water's surface and, more commonly, on structures above the water's surface. This atmospheric basking facilitates a significant increase in body temperature compared to aquatic basking (Boyer, 1965). Typical atmospheric basking sites include rocks, logs, and tangles of woody debris (Boyer, 1965; Lindeman, 1999). Individuals have also been observed basking on artificial objects such as dock fittings and riprap (personal observation). Basking sites used by turtles are generally stationary, at a far enough distance from shore so as to avoid potential terrestrial predators, near deep water, in direct sunlight for long periods of time each day, high above the water's surface, and with a clear view of the surrounding area (Boyer, 1965; Flaherty and Bider, 1984). Lindeman (1999) found correlations between substrata density and basking density of Map Turtles; areas that contained a higher abundance of deadwood supported much higher numbers of turtles – the more available habitat, the higher the number of turtles that can be supported.

Northern Map Turtles in Maryland are listed as a state endangered species. They are currently found only on the Lower Susquehanna River and its tributaries (Fig. 1), where habitat modifications (Pluto and Bellis, 1986; Moll and Moll, 2004), and human recreation (Bulte et al., 2010; Richards-Dimitrie, 2011) potentially threaten the viability of the population. Extreme water level fluctuations caused by the Conowingo Hydroelectric Dam reduce the amount of available basking habitat (rocks or logs), and high levels of human recreation below the dam may reduce or otherwise alter basking behavior (Richards-Dimitrie, 2011; Seigel et al. 2013)

Northern Map Turtles are extremely wary while basking, retreating into the water at the slightest disturbance (Pluto and Bellis, 1986; Lindeman, 1999). Many of the high-density basking areas on the Lower Susquehanna are located in close proximity to frequently traveled fishing canals, resulting in frequent abandonment of occupied basking sites (Seigel et al., 2013).

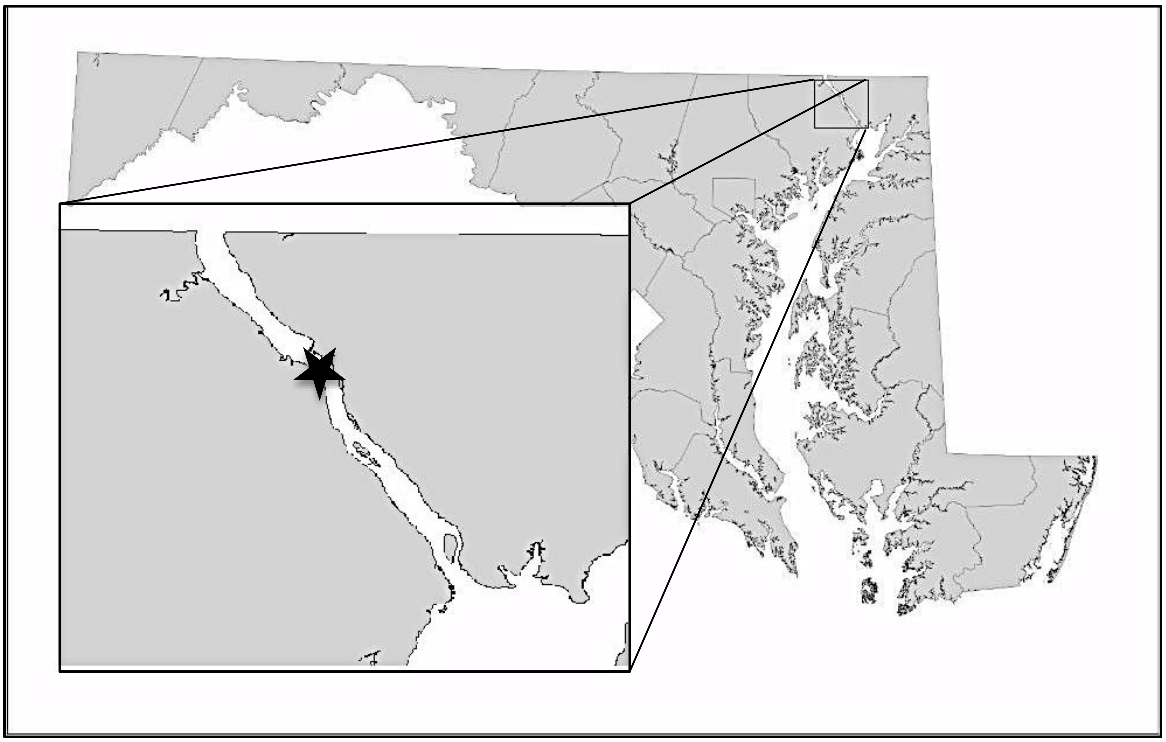

Figure 1. The lower Susquehanna River in Maryland. The upriver boundary is found at the Pennsylvania state line; the river eventually empties into the Chesapeake Bay. The black star marks the location of the Conowingo Hydroelectric Dam.

The extreme sexual dimorphism exhibited by Northern Map Turtles (Fig. 2) also influences habitat use: adult females are much larger in size and have superior swimming ability which allows them to use habitats that are further from shore in open water, while the smaller males tend to use habitats closer to shore with more cover (Carriere, 2007; Bulte et al., 2008). This suggests that males and females may bask in different areas, choose different substrates, and show differential responses to disturbances from humans.

I hypothesized that 1) *G. geographica* would exhibit basking site preference based on basking site properties 2) Dam flow and tide level would exhibit a synergistic relationship in influencing basking behavior and would be the most important abiotic factors in determining such behavior 3) Human recreation would be highest during the months that coincide with oogenesis and spermatogenesis 4) Slower-moving boats would be most likely to cause a basking disturbance. I also predicted that hypotheses one, three, and four would be influenced by gender as a result of the sexual dimorphism exhibited by Northern Map Turtles.

Figure 2. An adult male (left) and an adult female (right) Northern Map turtle.

Materials and Methods

Study Site

The Susquehanna River runs 747 km from Cooperstown, New York, through Pennsylvania, to Havre de Grace, Maryland, where it empties into the Chesapeake Bay (Lindsey et al., 1998). The Conowingo Hydroelectric Dam, the last and largest of multiple impoundments on the Susquehanna River, lies approximately 8 km below the Pennsylvania state line and 16 km upriver from the mouth of the Bay (Fig. 1). According to Richards-Dimitrie (2011), Northern Map turtle activity on the Lower Susquehanna is concentrated in the 230 ha island complex located approximately 8 km downriver from the dam and directly adjacent to Susquehanna State Park (Fig. 3). Therefore, this island complex served as the focal area of my study.

This site experiences tidal fluctuations from the Chesapeake Bay in addition to the variable flow regime produced by the hydroelectric dam (Lindsey et al., 1998). The dam releases water at a range of rates from 141.6 m^3/sec to 2600.6 m^3/sec during typical power generation (Fig. 4), but can produce much higher flow rates during flood conditions (Exelon Generation Company, 2009). Any water release over 2600.6 m/s is considered flood stage. The study site experienced a wide range of flow rates between 141.6 and 2600.6 m^3/s in a single day along with tidal fluctuations, often changing the availability of basking habitat on an hourly basis (Fig. 5).

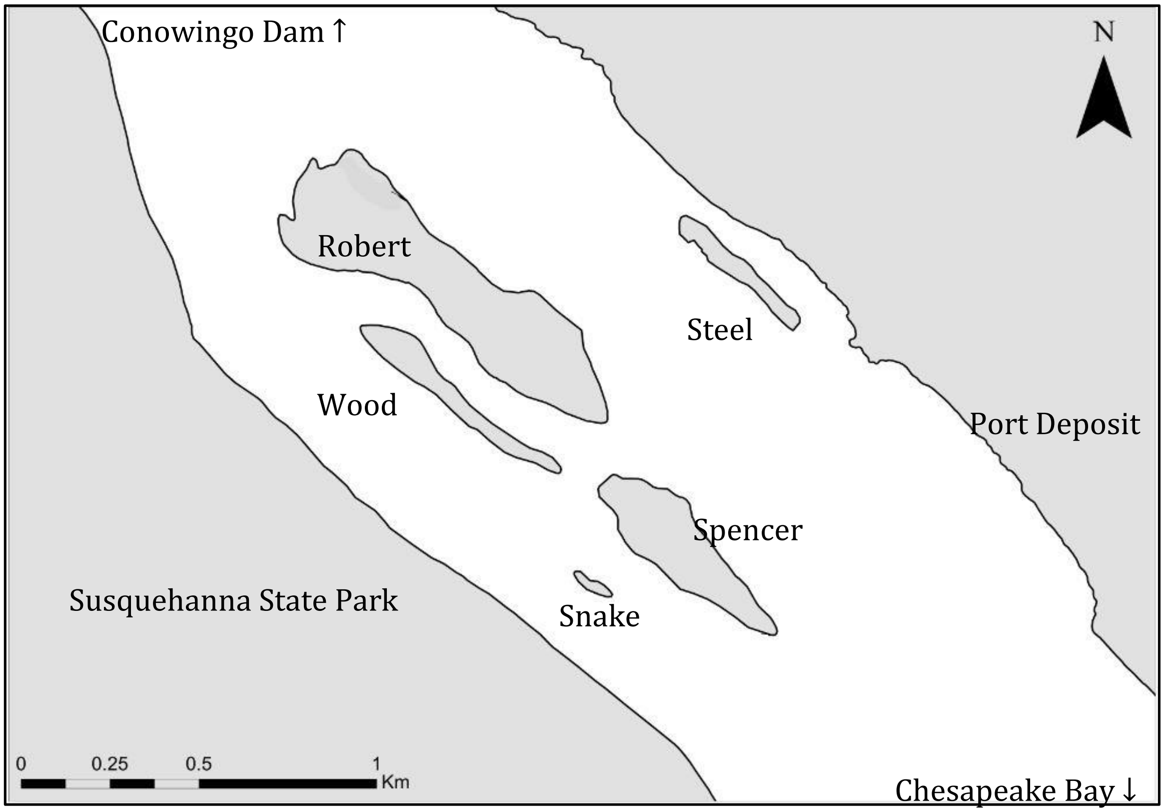

Figure 3. The Island Complex, located between Susquehanna State Park on the western shoreline and the town of Port Deposit on the eastern shoreline; located 8 km downriver from the Conowingo Hydroelectric Dam

Figure 4. (A) Flow at 141.6 m^3/s (B) The same location on the same day at 2600.6 m^3/s. Photos by Teal Richards-Dimitrie

Figure 5. Photos of adult female Northern Map turtles basking on a rock at 1245 hours (left) and 1330 hours (right) on the same day. After 45 minutes, only three of the original turtles remain.

Flow rates at flood stage typically only occurred after Pennsylvania and/or Northern Maryland experienced periods of heavy rainfall; single-day storms produced flood conditions that generally lasted one to two days. During my study, three large storms occurred: Hurricane Irene (August 2011),Tropical Storm Lee (September 2011), and Hurricane Sandy (2012). Each storm produced above-average flood conditions. Hurricane Irene produced rates of 25,900 m^3/s less than two weeks prior to Tropical Storm Lee; Lee resulted in the opening of 44 of 53 flood gates at 240,000 m^3/s; and Hurricane Sandy produced flow rates of 47,200 m^3/s (United States Geological Survey Instantaneous Data Archive). Flood conditions were typically much less drastic than these, yet still resulted in a temporary loss of basking habitat and, occasionally, permanent loss of basking and/or nesting habitat due to scouring (personal observation).

General Sampling Procedures

Basking surveys (Table 1) were conducted from 11 July to 24 October 2012, and from 30 May to 14 November 2013, totaling 102 person-days. Six remnant bridge piers extend from the Harford County Shoreline to the middle of Wood and Robert Islands (Fig. 3). These landmarks served as the upstream boundary for the sampling area, while the mid-point of Spencer Island marked the downstream boundary. All data were collected from the upstream tip of Spencer Island in a 4.6 m aluminum jon boat with a 15 hp Mercury® motor, on foot from the downstream tip of Wood Island, or during conditions deemed unsafe for boat travel (e.g. high winds, flood conditions), from the shoreline of Susquehanna State Park (Fig. 3).

Table 1. Key terms and definitions

Habitat Selection	The process or the action of choosing a particular habitat.
Basking survey	Visual sweep of the study site to identify basking turtles using a spotting scope.
Observation period	One 15-minute interval that consists of a single visual sweep of the entire study site.
Basking site	The physical structure on which a turtle is basking; rock or log.
Disturbance	Abandoning a basking site and entering the water in response to an external stimulus other than temperature.
Percent occupied	The number of exposed basking sites occupied by one or more turtles/ the total number of exposed basking sites.
Percent submerged	The number of basking sites completely covered by water/ the total number of basking sites.
Percent exposed	The number of basking sites not completely covered by water/ the total number of basking sites.
Model terms:	
Global model	The model containing all variables and all of their possible interactions.
Flow	Water flow from the hydroelectric dam: low (0-15,000 cubic feet per second (cfs))= little to no current movement; moderate (15,001-50,000 cfs) = moves small debris, produces visible riffles; high (≥50,001 cfs)= moves large debris, boat navigation difficult
Tide	Water flow from tidal fluctuations
Season	Summer (June-August) or Fall (September-November)
Air temperature	Air temperature (°C) in shade above a permeable surface

In order to represent times suitable for basking and all typical flow conditions, basking behavior was observed four days a week during eight-hour intervals. Three days were selected from Monday-Thursday and one day from Friday-Sunday to represent week day versus weekend boat traffic patterns. Days of the week and starting times (sunrise or 1200) were selected randomly using Microsoft® Excel 2010.

Visual encounter surveys were conducted every 15 minutes using a 60 x 80 mm Bushnell® spotting scope. This involved visually surveying the entire study site to identify the presence/absence of turtles and the basking substrate type (rock or log) they were using. For basking sites with turtles present, number of turtles, age class (based on relative body size, head size, and tail size (Ernst and Lovich, 2009)), and gender of individuals were recorded. This was important to note, as basking behavior in Northern Map turtles is heavily dependent on gender (Carriere, 2007; Bulte et al., 2008).

A Garmin GPSmap 60 was used to obtain a Universal Transverse Mercator (UTM) for each of 61 potential basking sites within 5 m accuracy. These basking sites were selected arbitrarily based on preliminary data collected from May-November 2011 and included sites that were sheltered from full current and sites that were exposed to full current. The less permanent structures (i.e. logs) were measured in June and September of 2012 and 2013 in order to detect any changes in placement. The UTMs were then plotted in ArcGIS 10 for analysis. The following properties were measured for each basking site: distance from land (m); distance (m) to nearest neighbor as evidence of clustering; and whether the site was located in open water or sheltered in the island complex. A cluster was defined as two or more sites within 5 m of one another.

Effect of Flow Regime

The amount of basking site surface exposed at a given flow rate, measured in conjunction with the presence of turtles, shows the effects of flow rate disturbance on basking behavior. Water level changes were recorded every 60 minutes by shading the submerged portions of each basking site on a map of the study site. These data show a rough estimate of the change in proportion of the physical surface covered for each potential basking site over time. The number of submerged (i.e. unavailable) basking sites and the number of exposed sites were determined using the same method, along with the number of exposed sites that were actually occupied by basking turtles. Those data were represented as a proportion of the total sites exposed. These data provided a measurement of relative basking site size/height, as some sites are only exposed during low water, while other sites are exposed regardless of water level. The data were then compared with the United States Geological Survey (USGS) Instantaneous Data Archive (IDA) available for the Conowingo Dam and with the daily tide schedule for Port Deposit, MD (http://www.tides4fishing.com/us/maryland/port-deposit). To account for the time lag between hydroelectric water release and the resultant increase in water level at the Island Complex, the observed map data were compared with the IDA recordings listed 45 minutes before the designated observation period.

Effects of Human Recreation

Boat traffic patterns were documented during visual encounter surveys. These patterns were recorded on the field site map mentioned previously and were represented by a vector indicating the vessel's path and trajectory. Along with the corresponding date and time, these data were used to determine hourly, daily, and seasonal boat traffic patterns. Any resulting disturbance, defined as the abandonment of a basking site in response to an external stimulus (e.g. boat, bird, etc.), was also recorded, including the vessel type and time of disturbance. Due to time constraints, individual turtles were not given identifying marks that were visible from long distances; therefore, time to recovery for individual turtles could not be measured.

Effect of Environmental Conditions

Numerous studies have shown that environmental conditions heavily impact basking activity in aquatic turtles (e.g., Boyer, 1965; Crawford, 1983; Ben-Ezra, 2008). In order to account for environmental conditions as a factor in habitat selection, the following covariates were measured: Using a Control Company Long-Stem Thermometer, air temperature and water temperature were recorded to the nearest tenth of a degree °C. A Kestrel® 2500 Pocket Weather Meter was used to measure relative humidity and average wind speed (knots). Cloud cover was categorized as sunny (100% sun), partly cloudy (25% clouds), partly sunny (25% sun), overcast (100% clouds), and raining.

Statistical Analysis

The probability of site properties on basking habitat selection was modeled using a generalized linear model in R (The R Foundation for Statistical Computing, 2014). A scale term was included to correct for overdispersion in the data. The variables included were substrate type, distance to land, nearest neighbor distance, sheltered or exposed (to full current), and exposure time. The model was first run for males, and then for females.

The effect of dam flow and tide level on basking activity was analyzed using an information theoretic approach (Burnham and Anderson, 2002; Mazerolle, 2006). I ran three models: flow; tide; and the interaction of flow and tide; each model set was run for logs and for rocks to separate the effects of substrate type, and then run for males and for females under each substrate type category. Additionally, I analyzed the influence of flow and tide level paired with three other key abiotic factors. Forty-two candidate models were created *a priori*; variables included were season, flow, tide, air temperature, and square-transformed temperature. Although over-parameterization was not an issue with such a large dataset, the only environmental variable used was air temperature, as it was the best indicator of emergent basking (Boyer, 1965; Crawford et al., 1983; Coleman and Gutberlet, 2008). A generalized linear model was applied to fit the models in R. The best models were ranked and compared using Akaike's Information Criterion (AIC).

Descriptive statistics were used to plot boat traffic against month in order to identify seasonal patterns that coincided with nesting, spermatogenesis, and mating. Water vessel type was plotted against disturbance counts to determine the most likely cause of basking disturbance, as well as analyzed in a Chi-squared contingency table to compare observation periods with disturbances to those without disturbances. Significance was accepted at $\alpha = 0.05$.

Results

Basking Site Selection

Males and females both basked on rocks more often than on logs, but females basked more often than males, in general (Fig. 6). No basking site was occupied more than 21% of the time (Table 2). The most frequently used sites were fairly evenly split between rocks (n=4) and logs (n=3); however, the most frequently used sites overall and for each gender were rocks (Table 2). For both genders, no combination of basking site variables had a significant effect on basking site selection; (Table 3).

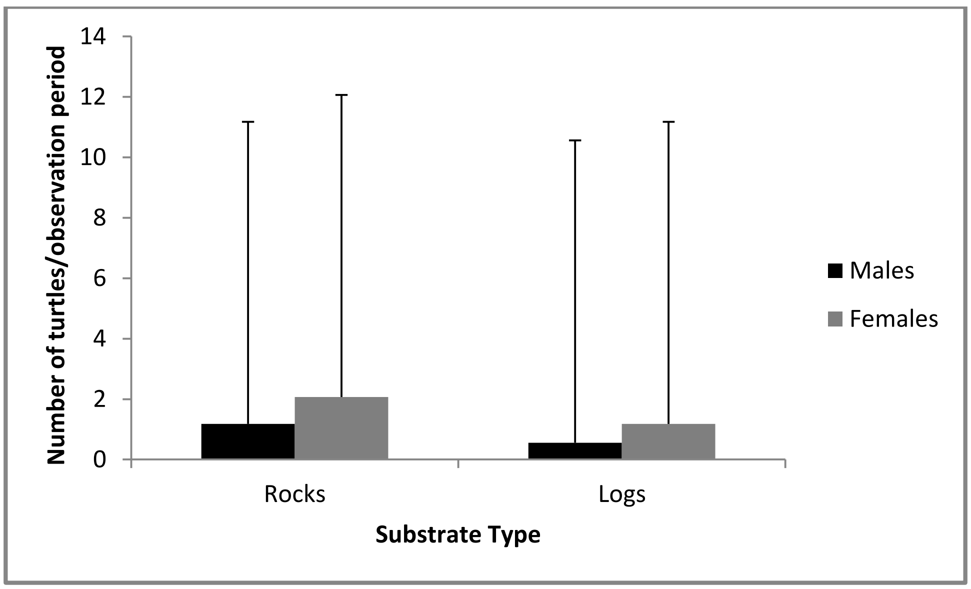

Figure 6. Basking substrate use based on gender, measured as the mean number of turtles basking on each substrate type per observation period (15-minute intervals).

Table 2. Basking sites listed according to frequency of general use (observation periods occupied/total number of observation periods). Frequency of use by gender is also included: the top ranked basking site for each gender is bolded. Time exposed = observation periods not submerged/total observation periods.

Site Name	Site Type	Time Occupied - Overall (%)	Time Occupied – Females (%)	Time Occupied – Males (%)	Time Exposed (%)
Platform	Rock	21%	**19.38**	4.97	92.41
Mud Tree Stump	Log	15.1-20%	11.95	5.18	84.46
Elephant Log	Log	10.1-15%	11.26	4.71	90.68
Bunny	Rock		5.05	**10.19**	39.9
Triangle Cluster	Rock		7.86	6.39	91.89
Island Rock	Rock		9.63	5.83	24.88
Fatty Snag	Log		9.71	5.18	62.35
Skinny Leg	Log	5.1-10%	6.35	5.1	63.22
Roughy	Rock		7.68	1.95	82.56
114	Rock		7.08	1.82	62.18
Baby Elephant	Rock		7.21	1.04	59.59
Peninsula	Rock		5.14	1.95	47.67
Dots	Rock		5.05	2.38	54.58
Mud Tree	Log		1.99	3.63	90.33
Flat rocks	Rock		2.21	3.46	51.13
Tiny log rock	Rock		4.45	2.38	87.92
Twins L	Rock		2.68	3.11	66.5
Triangle	Rock	0-5%	3.11	2.68	100
Party	Log		4.23	1.21	28.85
August	Rock		2.64	2.72	36.27
113	Rock		3.37	1.13	68.92
Holey Tree	Log		2.98	1.64	63.91
Log Rock	Rock		3.37	0.82	95.86
Elephant Cluster	Rock		3.28	0.61	91.02
Crash	Rock		3.02	1.34	26.78
112	Rock		2.16	1.51	92.58
Mill	Rock		2.9	0.52	50.44
Shallow Log	Log		2.25	1	32.13
Broken Log	Log		1.73	1.26	62.35
SC2	Rock		2.21	0.26	83.42
September	Rock		1.3	1.39	32.47

Bottom rocks	Rock		1.34	1.21	41.63
July	Rock		1.26	1.21	48.36
Shallow Rocks	Rock		1.04	1.39	23.84
Fish	Rock		1.56	0.7	18.66
Wood Sticks	Log		1	0.82	56.83
Kristen	Rock		1.3	0	95.86
Nicole	Rock		1.21	0.13	65.29
Pyramid	Rock		0.61	0.78	79.11
111	Rock		1	0.35	74.44
Cigar	Rock		1.17	0.26	19.35
Middle	Rock	0-5%	1.08	0	58.21
Park	Rock		0.78	0.22	42.15
Pyramid cluster	Rock		0.78	0.13	59.59
Swim	Rock		0.87	0	34.2
SC1	Rock		0.74	0	95.34
BP6	Rock		0.57	0.22	100
Trick Log	Log		0.22	0.31	42.84
BP4	Rock		0.26	0.13	100
BP3	Rock		0.22	0	100
BP5	Rock		0.09	0.09	100
Bolt	Rock		0	0	100
BP1	Rock		0	0	100
BP2	Rock		0	0	100
Elephant Rock	Rock		0	0	100
IBP Log	Log		0	0	60.45
Island Bridge Pier (IBP)	Rock		0	0	100
Mini	Rock		0	0	69.09
Tangle	Log		0	0	58.73

Table 3. Comparison of p-values for basking site property variables between males and females. Significance level of $\alpha<0.05$. Substrate type = rock or log; Exposure time = number of observation periods in which the basking was not submerged/total number of observation periods.

Variable	P-value Males	P-value Females
Substrate type	0.219	0.15
Distance from land (m)	0.463	0.12
Nearest neighbor distance (m)	0.764	0.645
Open water/Sheltered	0.908	0.804
Exposure time	0.166	0.513

Effects of Flow and Tide on Basking Behavior

Before looking at all five abiotic variables together, it is important to look at the impacts of hydroelectric flow and tide level separately. As flow rates from the dam increased, the proportion of available basking sites that were occupied by basking turtles decreased (Fig. 7). As with flow rates, as the tide level increased, the percent of occupied basking sites out of the total number of basking sites decreased (Fig. 8). I used an information theoretic approach to first look at the effects of flow and tide only on basking activity. For each sex/substrate type combination, except for males basking on logs, the interaction model yielded the lowest AIC value (Table 4). For males on logs, dam flow by itself yielded the lowest AIC value, but the ΔAIC values are within two digits for all three models. The low pseudo-r^2 values show that no models had a strong effect on basking activity.

After accounting for additional abiotic variables, the information theoretic approach showed that for all combinations of gender and substrate type, the global model yielded the lowest AICc values (Table 5). Despite being the top model, it explained little of the variation in this system. It is important to note that, although not significant, the variation explained by rocks was higher than that explained by logs for both genders (Table 5). The top model for all four gender/substrate type combinations was as follows:

$$B = F + T + S + A + A^2 + F*T + F*S + F*A + F*A^2 + T*S + T*A + T*A^2 + S*A + S*A^2 + A*A^2$$

where B is basking activity, F is flow rate, T is tide level, S is season, A is air temperature, and A^2 corrected air temperature. The model includes all five parameters with all possible interactions between those terms. ΔAIC scores between the global model and the second model were greater than 2 and considered not plausible for all four combinations of gender and basking substrate type: females and rocks; females and logs; males and rocks; males and logs.

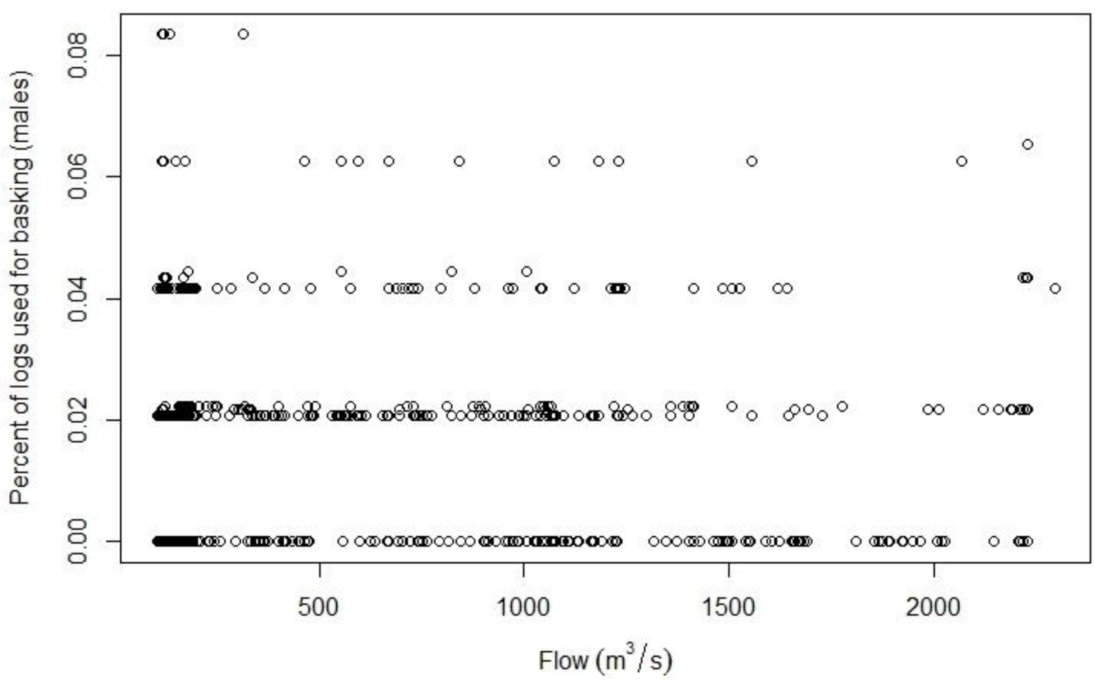

Figure 7a. The percent of available basking sites that were occupied by basking turtles in response to flow rates (cubic meters per second) from the Conowingo Hydroelectric Dam. Each point represents one 15-minute observation period and depicts basking activity for any **males using logs**.

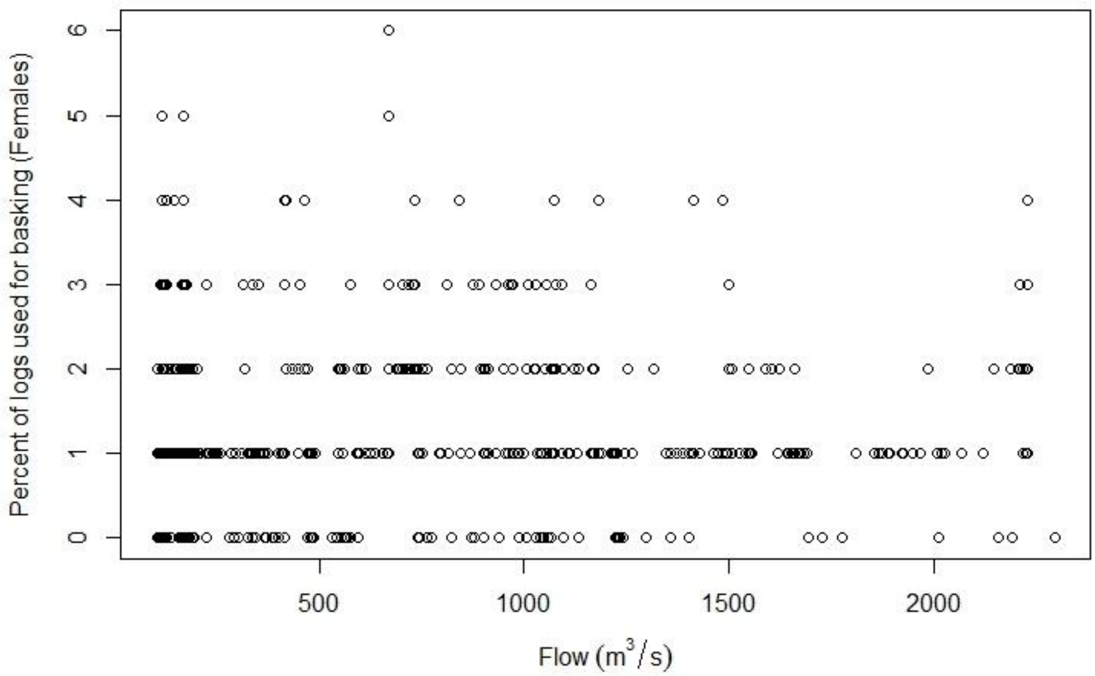

Figure 7b. The percent of available basking sites that were occupied by basking turtles in response to flow rates (cubic meters per second) from the Conowingo Hydroelectric Dam. Each point represents one 15-minute observation period and depicts basking activity for any **females using logs**.

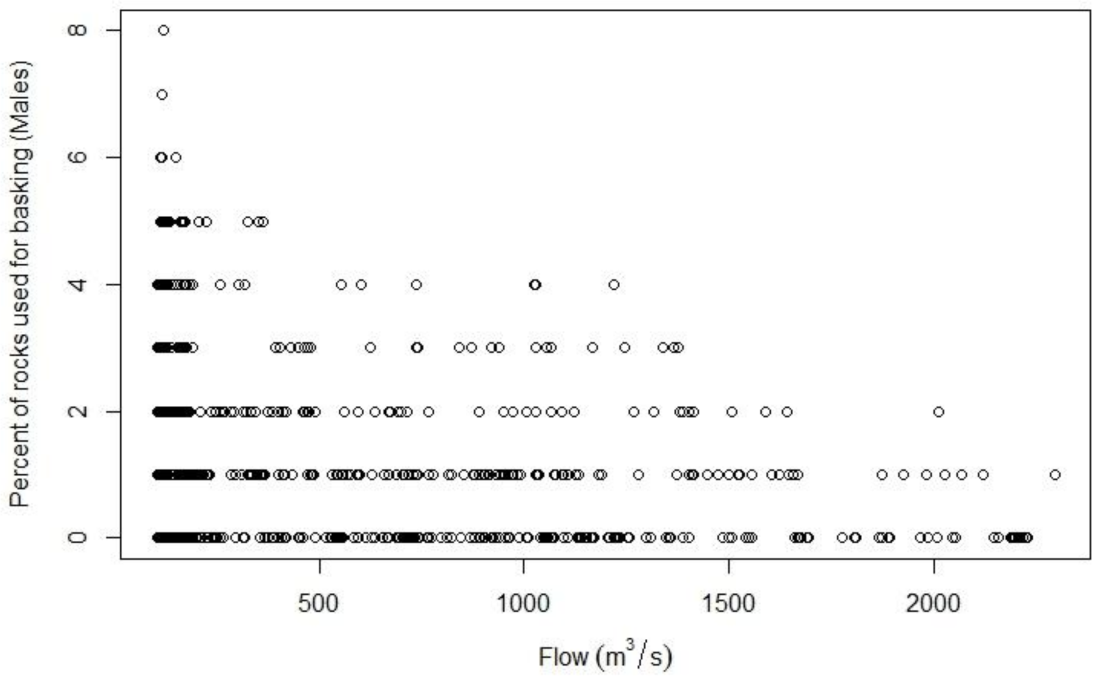

Figure 7c. The percent of available basking sites that were occupied by basking turtles in response to flow rates (cubic meters per second) from the Conowingo Hydroelectric Dam. Each point represents one 15-minute observation period and depicts basking activity for any **males using rocks**.

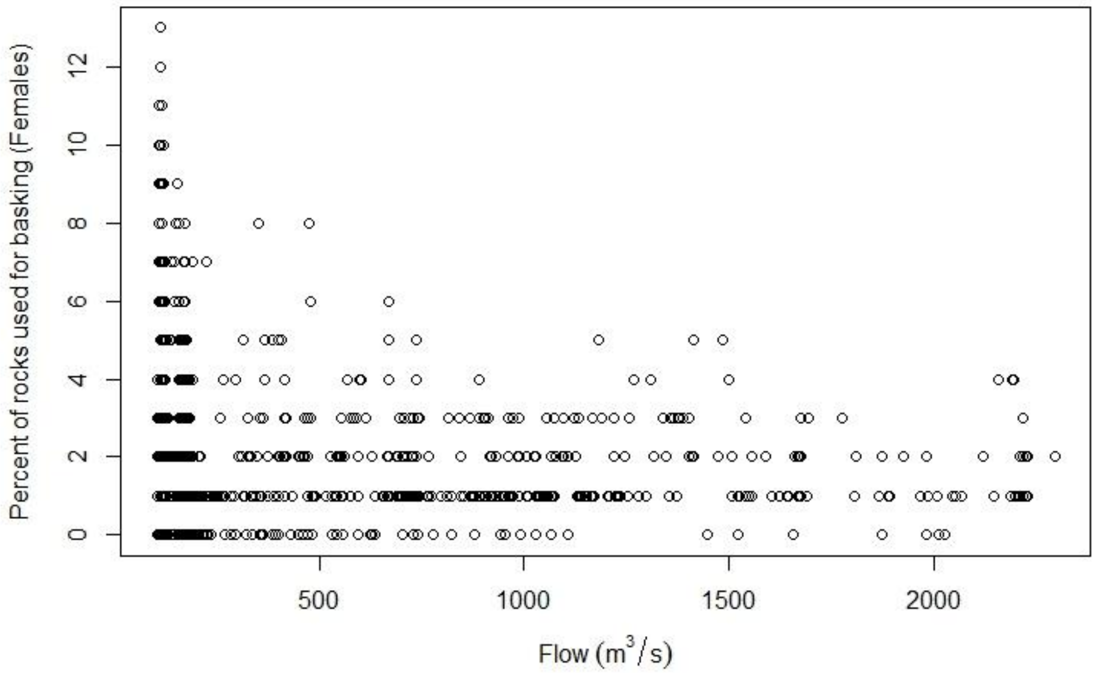

Figure 7d. The percent of available basking sites that were occupied by basking turtles in response to flow rates (cubic meters per second) from the Conowingo Hydroelectric Dam. Each point represents one 15-minute observation period and depicts basking activity for any **females using rocks**.

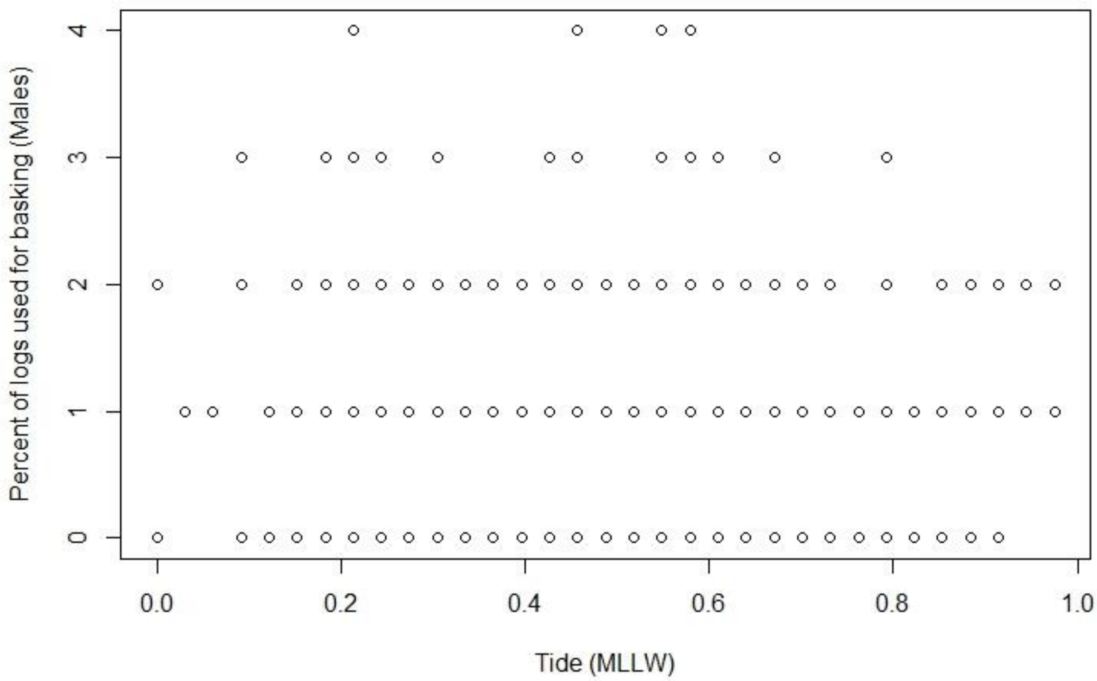

Figure 8a. The percent of available basking sites that are occupied, in response to tide level, measured as Mean Lower Low Water (MLLW). Each point represents one 15-minute observation period and depicts basking activity for any **males using logs**.

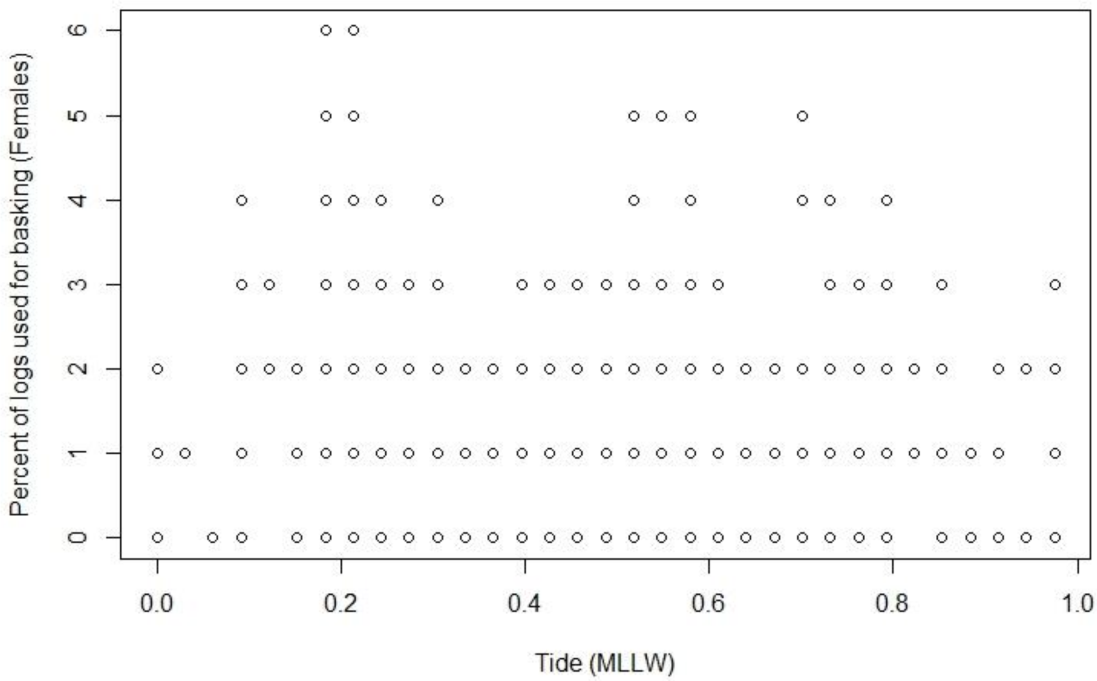

Figure 8b. The percent of available basking sites that are occupied, in response to tide level, measured as Mean Lower Low Water (MLLW). Each point represents one 15-minute observation period and depicts basking activity for any **females using logs**.

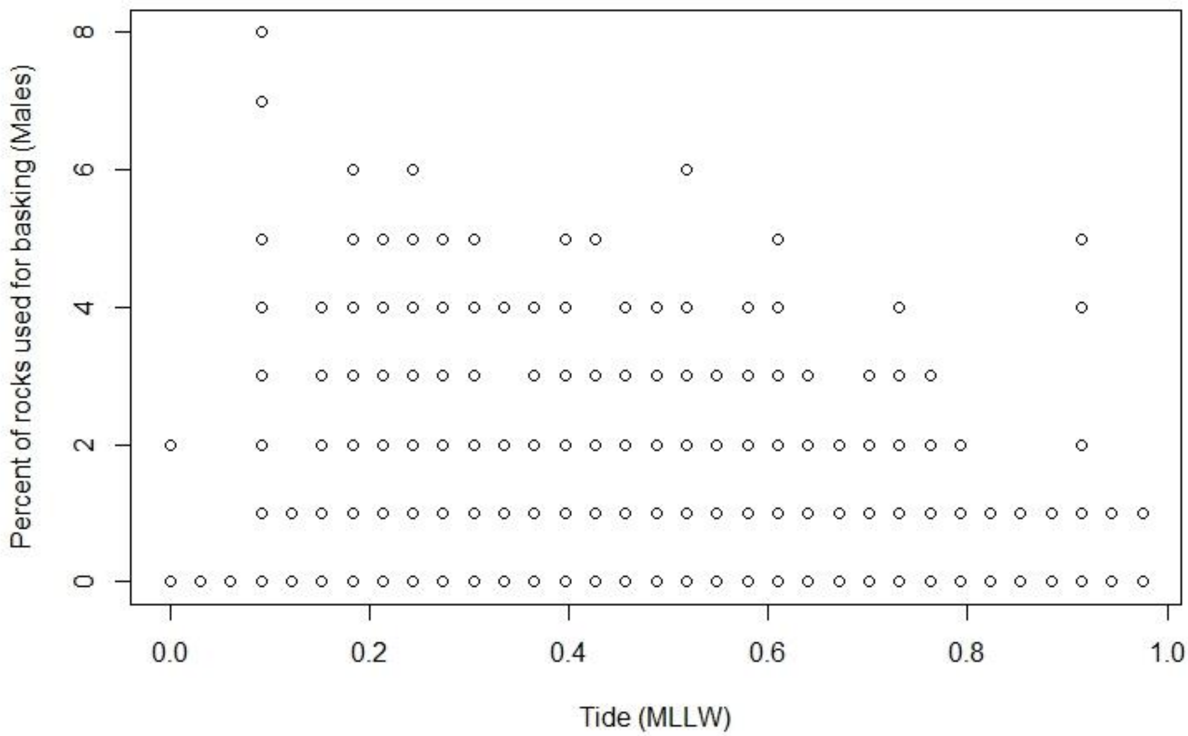

Figure 8c. The percent of available basking sites that are occupied, in response to tide level, measured as Mean Lower Low Water (MLLW). Each point represents one 15-minute observation period and depicts basking activity for any **males using rocks**.

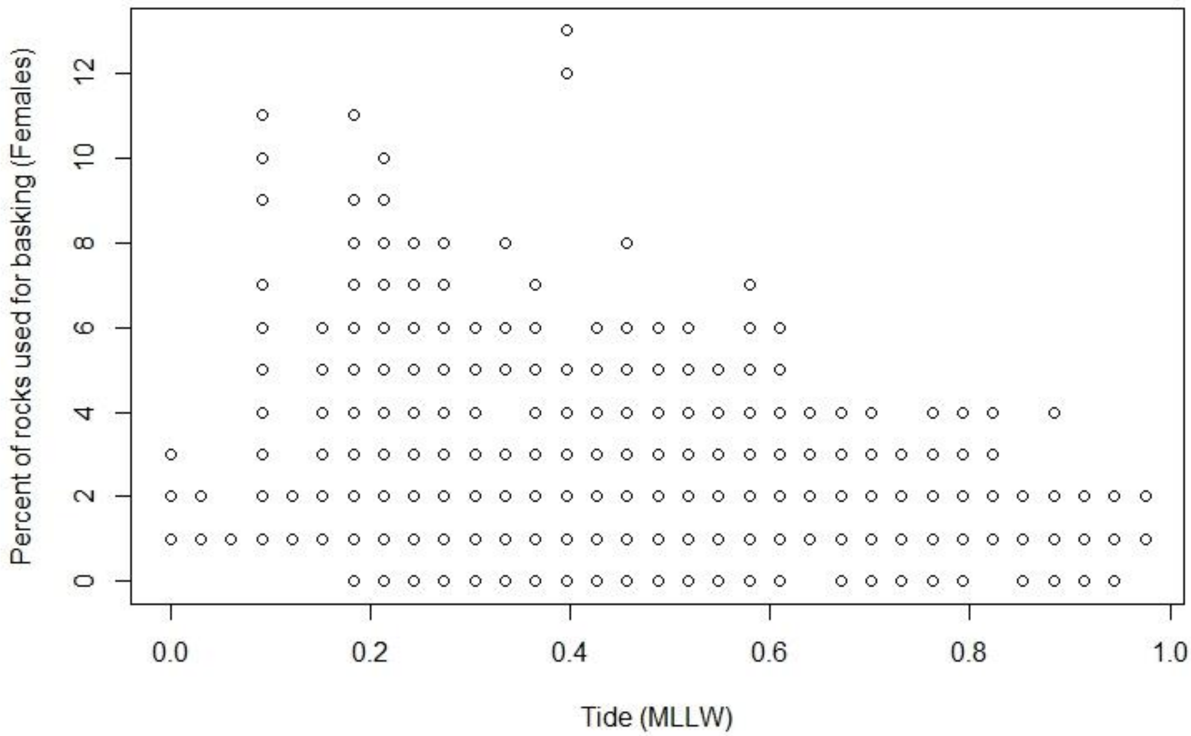

Figure 8d. The percent of available basking sites that are occupied, in response to tide level, measured as Mean Lower Low Water (MLLW). Each point represents one 15-minute observation period and depicts basking activity for any **females using rocks**.

Table 4. AIC scores for flow, tide, and their interaction for each combination of sex and substrate type: males basking on logs, males basking on rocks, females basking on logs, and females basking on rocks. K = number of parameters plus one degree of freedom; AICc = corrected AIC score based on residual deviance

Sex/Substrate Type	Model	k	AIC	AICc	Pseudo-R^2
Males/Logs	Flow	2	2142	2142	0.003
	Tide	2	2146	2146	0.009
	Flow*Tide	3	2145	2145	0.004
Males/Rocks	Flow	2	409345	409345	0.064
	Tide	2	411815	411815	0.054
	Flow*Tide	3	397807	397807	0.114
Females/Logs	Flow	2	2846	2846	0.014
	Tide	2	2861	2861	0.003
	Flow*Tide	3	2839	2839	0.023
Females/Rocks	Flow	2	530539	530539	0.032
	Tide	2	524575	524575	0.059
	Flow*Tide	3	516432	516432	0.096

Table 5. AIC scores for each top model for each gender/substrate type combination. K = number of parameters plus one degree of freedom; AICc = corrected AIC score based on residual deviance.

Gender/substrate type	k	AIC	AICc	Pseudo-R^2
Males/Rocks	15	310656	310657	0.176
Males/Logs	15	1829	1830	0.131
Females/Rocks	15	406765	406765	0.184
Females/Logs	15	2317	2318	0.149

Effects of Seasonal Recreational Activities on Basking Behavior

Nesting and secondary oogenesis in Northern Map Turtles occurs in late spring and early summer (Lindeman, 2013), while spermatogenesis and mating are known to occur in late summer and fall (Coleman and Gutberlet, 2008; Lindeman, 2013). My data show that boat traffic exhibited a unimodal pattern for both years combined from June to November, with the highest amount of boat traffic occurring during the month of September (Fig. 9) at a mean of 7.55 boats per day. November had the least amount of boat traffic at 2.5 boats per day.

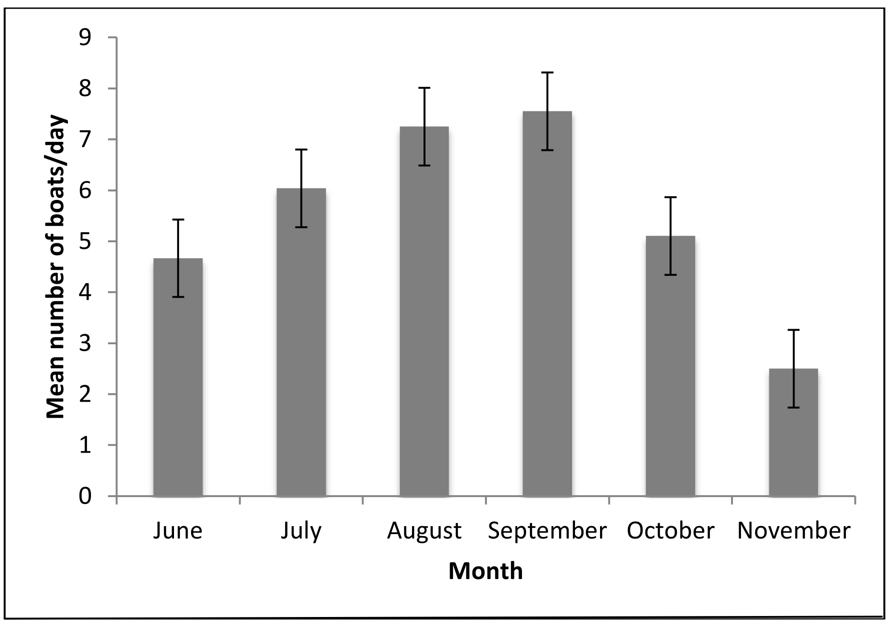

Figure 9. Seasonal boat traffic patterns for June-November of 2012 and 2013, represented by the mean number of boats sighted per day for each month.

Seasonal patterns of disturbance were slightly different than the seasonal boat traffic patterns. The month of September saw the highest mean number of basking disturbances per day, followed closely by the month of October (Fig. 10). Disturbance rates were moderate from June-August and were lowest in November.

The gender-specific responses to disturbance among months mimics that of the general response to basking disturbances: September and October had the most disturbances for both genders, with moderate rates during the summer months (Fig. 11). Females were disturbed more often than males in all months; August was the only month where disturbance rates were fairly similar.

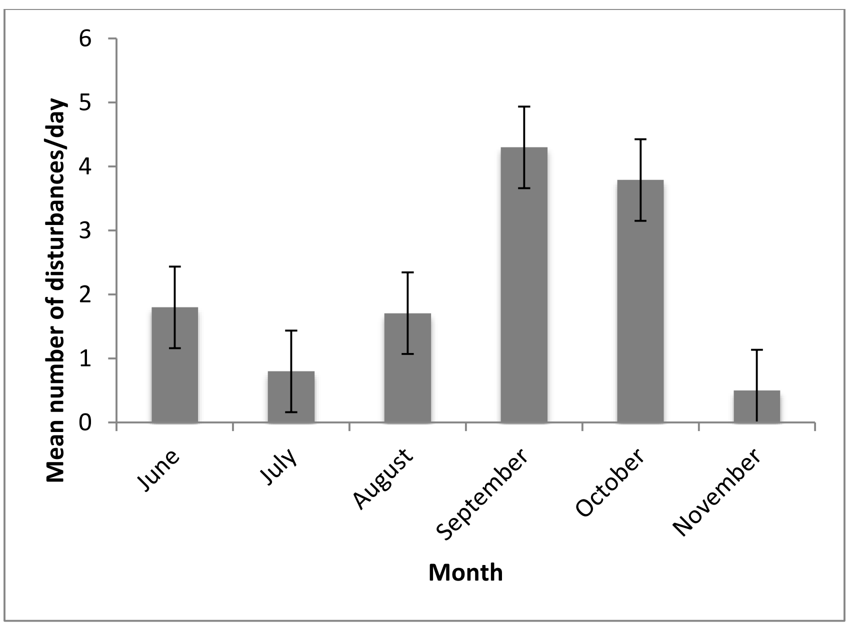

Figure 10. The mean number of basking disturbances per day, broken down by month; an event was considered a disturbance when one or more turtles abandoned a basking site in response to an external stimulus

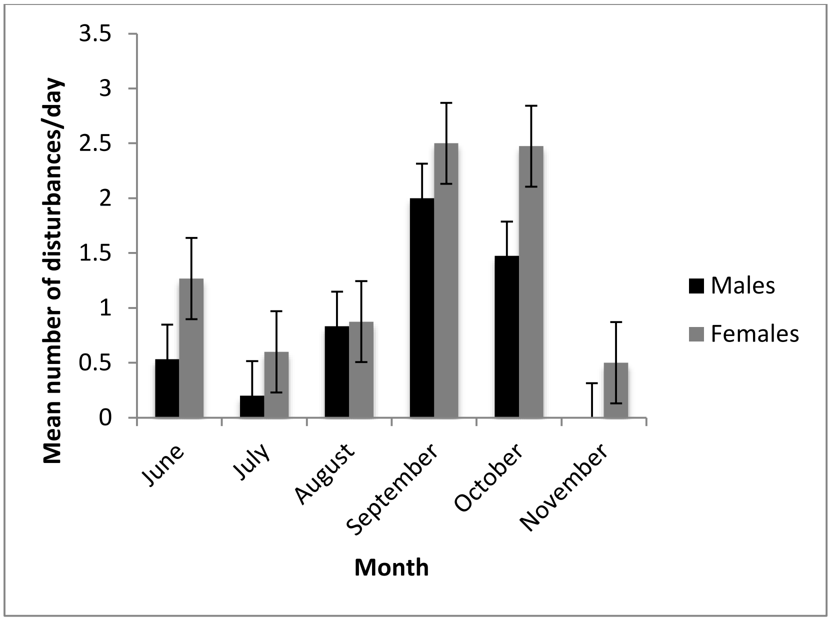

Figure 11. The mean number of basking disturbances per day per month for males (dark bars) and females (light bars); an event was considered a disturbance when one or more turtles abandoned a basking site in response to an external stimulus

The most common boat types at the study site were slow-moving fishing boats and kayaks, while the least common vessels were speed boats; individuals swimming in the river or hiking on the shoreline occasionally caused a disturbance as well (Fig. 12). Slow-moving fishing boats were the most commonly sighted boat on the river, however, kayaks had a higher disturbance rate (boats 22%, kayaks 29%; Fig. 12). Although the disturbance rate for swimmers and hikers was 100%, this type of disturbance occurred much less often than for fishing boats and kayaks. Chi-Square analysis showed that basking activity during observation periods with disturbances was significantly lower than from observation periods without disturbances (X^2=33.17, df=4, p<0.0001).

Along with the seasonal boat traffic patterns, environmental conditions followed seasonal patterns as well. According to studies on turtle basking for thermoregulation, as temperature increases, basking activity increases and/or is more likely (Boyer, 1965; Crawford, 1986). My data reflect this pattern and they also show that when water temperature is lower than air temperature, aerial basking activity increases. Figure 13 shows the hourly basking patterns for 12 June 2013 based on air and water temperature; as the difference between air temperature and water temperature increases, so the percent of available basking sites that are occupied by turtles.

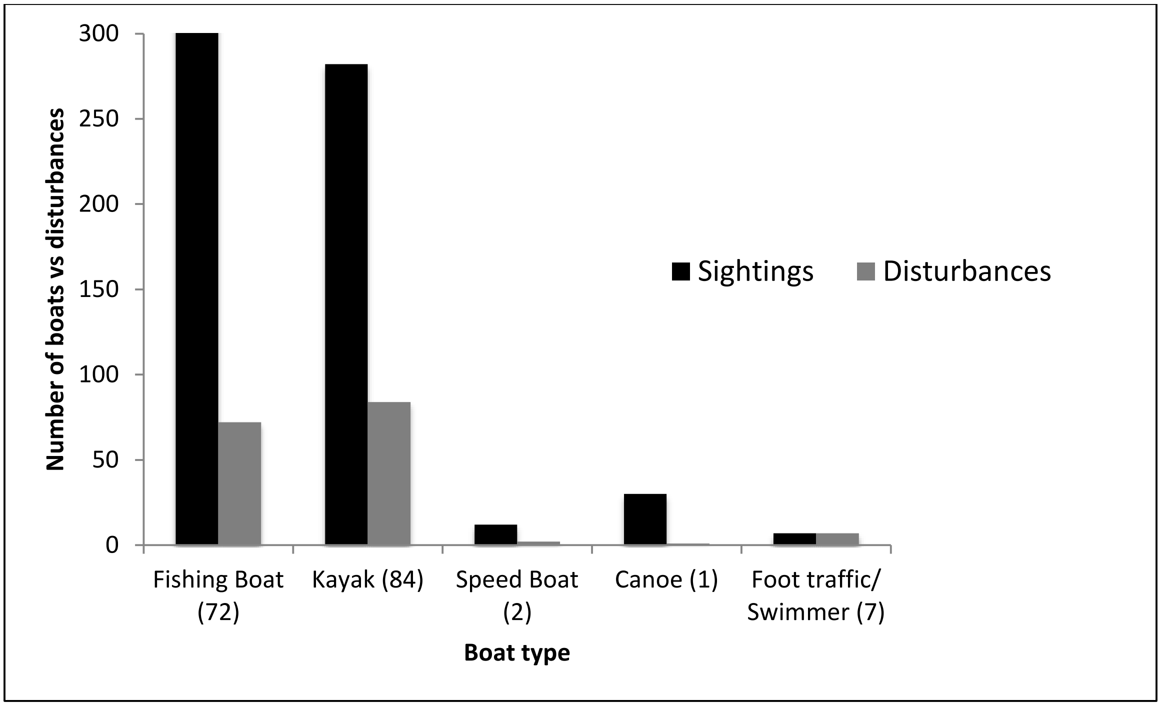

Figure 12. Count data for the number of sightings (dark bars) for each boat type seen at the study site compared to the number of disturbances (light bars) caused by that boat type; the actual number of disturbances can be found in parentheses next to each boat type. Fishing boat = slow-moving boats that did not produce a powerful wake; Speed boat = fast-moving boats or jet skis that produced a powerful wake; Foot traffic/swimmer = individuals swimming in the river or hiking on the nearest shoreline.

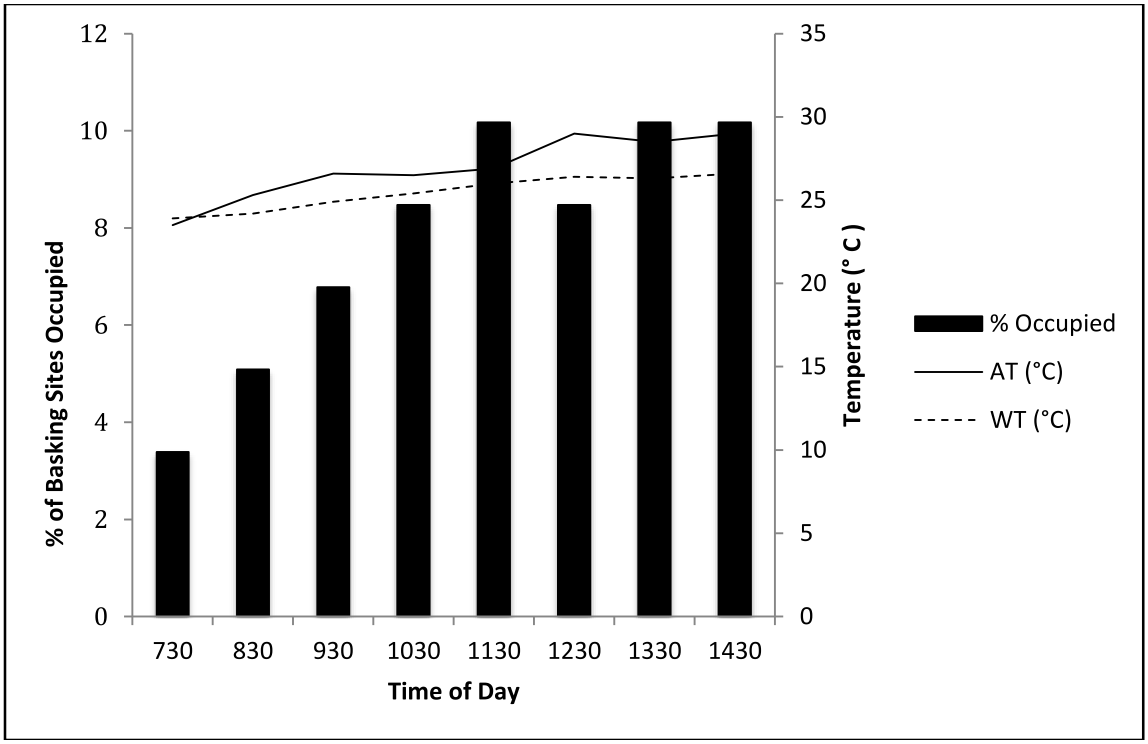

Figure 13. Depicts the percent of basking sites occupied in response to hourly air temperature and water temperature for 12 June 2013.

Discussion

Basking Site Selection

The hypothesis that basking habitat selection occurred based on site characteristics was not supported. Despite what was predicted, this lack of support follows the results of a number of previous studies investigating the link between habitat characteristics and basking behavior (Flaherty and Bider, 1984; Pluto and Bellis, 1986; and Lindeman, 1999). These studies looked at the influence of basking substrate type, including size and shape and abundance, on whether or not particular substrates were used for basking. Lindeman (1999) and Pluto and Bellis (1986) found that the abundance of substrate and the arrangement of it in the landscape did affect the level of basking activity, along with some influence of the angle at which the basking site emerges from the water (Lindeman, 1999). However, Flaherty and Bider (1984) investigated physical properties of basking sites, such as size, shape, surrounding cover, surrounding substrate, etc. with no significant effects on basking behavior from any of them. They postulated that there must be some sort of social cue from other basking turtles that draws an individual to one site over another site.

However, it is important to note the higher utilization of rocks over logs in both genders. It is possible that this is the result of the large rock to log ratio at the study site (i.e. there are more rocks than logs to choose from to begin with, regardless of additional habitat selection factors), but it could also be due to the thermoregulatory properties of rock versus wood. According to Simpson (1993) and Steinhagen (1977), wood has a lower ability than rock to conduct heat, and wet wood is less able to conduct heat than dry wood. All 13 of the logs included in my study were water-saturated, meaning they take even longer to reach the temperature of surrounding rocks (which are not saturated with water) than would dry logs in the same location. This lower ability to conduct heat could be more of an issue for females basking on logs as they require longer basking periods to reach optimal temperatures due to their larger body size (Bulte and Blouin-Demers, 2010). Their study showed that females still had a lower daily maximum body temperature than males, despite spending more time basking than males and other smaller turtles – a larger body surface area-to- volume ratio requires longer periods of time to reach similar temperatures.

The top ten sites for females slightly favored rocks over logs (60% rocks, 40% logs), while the top ten sites for males showed an exact 50/50 split. This seems to counter the argument that there is a preference for rocks; however, the logs represented in the top ten were generally only available during moderate to high water levels. During low water, virtually 100% of the rocks observed in this study were available. Out of the 13 logs observed, 11 of these were located on the shoreline; as water levels decreased, the logs eventually rested completely on land where they were no longer accessible. While, at times of high water, they were some of the only basking sites available.

Basking site slope may play a role in basking site selection, followed by substrate type. Coleman (2006) and Lindeman (2013) point out that the majority of basking habitat used by map turtles in the southeastern US is characterized by a slope of about 45 degrees, allowing them to climb to greater heights to gain better visibility. Unfortunately, I did not measure site slope due to logistical reasons and this variable will need to be measured for the basking sites at my field site. No patterns of similarity existed amongst frequently or infrequently used basking habitat based on the properties investigated in this study.

Effects of Flow and Tide on Basking Behavior

While addressing flow and tide only, the model selection results show that the effect of water level on decreasing basking activity is due more to the interaction between tide levels and dam flow, rather than by one or the other. Even though the model for flow alone was the best model for males basking on rocks, the other models were close enough in value that they are just as plausible in explaining the variance in this system. Therefore, flow and tide together contribute the most to the rapid habitat loss depicted in Figs. 8 and 9.

According to Lindeman (1999), there is a direct correlation between the abundance of basking sites and the number of turtles that can be supported by the habitat. This close link between site abundance and basking activity could produce problems (e.g. inability to reach optimal body temperature, get rid of skin parasites, etc.) in a system where site abundance is not a fixed quantity. There may be enough basking habitat present to support a large population's basking needs during low water conditions, but the maximum number of possible basking sites is not available 100% of the time.

When accounting for additional abiotic influences via model selection, there was a marked decrease in the proportion of the variance explained by flow and tide. In fact, there was not much variance explained by all factors combined. This is partly due to the fact that a large subset of the sites were used less than one percent of the time (n=17) and, therefore, were not contributing any information about basking activity. Additionally, only basking activity associated with flow, tide, substrate type, season, and temperature was addressed. There are most likely other contributing factors that were overlooked, including the data on individual site properties used to address site preference. From those results, however, it is clear that substrate slope may be the only additional site-specific factor worth adding to this model. As Flaherty and Bider (1984) suggested, there is quite possibly a large social component to habitat selection that needs to be addressed in such a gregarious species.

Effects of Seasonal Recreation Activities on Basking Behavior

My hypothesis that boat traffic would peak during nesting season and fall spermatogenesis/mating was only partially supported. Due to logistical and weather constraints, observations were not taken during May and for part of June for both years. Therefore, my data may not accurately reflect the amount of boat traffic that is present during the beginning of nesting season. However, high boat traffic during the fall may pose a problem for successful spermatogenesis and mating as potential disturbances increase. According to Lindeman (2013), spermatogenesis begins in June and peaks in September; boat traffic increases starting in June and peaks in September. With increased traffic comes increased disturbance rates (Fig. 13), and increased disturbances limit basking time which can be detrimental for this temperature-dependent biological function (Lindeman, 2013).

Northern Map turtles mate at communal hibernacula in the fall (Carriere, 2007; Lindeman, 2013), although not much else is known about this little-studied aspect of map turtle biology. Thermoregulation via basking is physiologically important for turtles making their way back to these hibernacula to mate during this stretch of time. Limited basking time as a result of high boat traffic could potentially cause some individuals to not complete these physiological cycles in time to mate; and these physiological effects need to be investigated to determine whether the result would indeed be detrimental to successful mating.

When comparing seasonal boat traffic patterns (Fig. 10) to the resultant seasonal disturbance patterns (Fig. 11), the patterns were not identical. Boat traffic increased from June to September, then gradually decreased again, while disturbance rates were lowest in July and November, moderate in June and August, and very high in September and October. The drop in disturbance rates for the month of July may be due to the fact that water levels were extremely low at this time of the summer, limiting the number of boats that could access the shallowest areas of the Island Complex where the majority of the basking sites were located. This was also when air temperatures were highest during both years. Some days saw less basking activity than others due to environmental cues and , therefore, less turtles were present to be subjected to disturbance. As summer transitioned into fall, higher water levels allowed better access to the deeper channels located in the Island Complex, and the number of boats in the Complex increased. Fall was also marked by a greater difference in air and water temperature; as each day progressed, the air became warmer than the water, drawing the turtles out to bask aerially. The lowest disturbance rates in November reflect the decline in both human recreation and turtle activity as temperatures decreased and the shift toward hibernation began.

The pattern of disturbance for each gender (Fig. 12) did mirror the general disturbance patterns for the site as a whole. Both sexes showed low disturbance rates in July and November, moderate rates in June and August, and the highest rates in

September. However, females were disturbed consistently more often than males were. My data show that all basking sites but one were more frequently occupied by females than by males, verifying that basking activity was female-biased for this population (Table 1); therefore more females were exposed to potential disturbances. The higher disturbance rates for females may also be due to the fact that abandonment of basking sites is almost exclusively based on sight (Waters, 1974; Lindeman, 2013).

My hypothesis that slow-moving boats would produce greater disturbance rates than those moving more rapidly was supported by my data. The higher proportion of kayak disturbances in comparison to other boat types is likely a result of the following: the slow movement of kayaks mimics that of a predator; they require dynamic paddle movement, making them easily visible; their small size allows them to linger much closer to shore and to basking sites than other vessel types on the river. Jon boats and speed boats typically moved by quickly enough that it seemed the turtles did not have time to identify them as a potential threat and/or they were not close enough to alarm basking individuals. Canoes, although relatively rare on this stretch of the Susquehanna, behaved similarly to kayaks and should be placed in the same category.

Future Research and Management Suggestions

In order to address unanswered questions about basking habitat preference, I suggest (1) determining the slope of each basking site and adding it as a new variable to the models that I ran; (2) investigating possible social cues for habitat selection implied by Flaherty and Bider (1984), and (3) addressing the thermal properties of rocks versus logs in a more detailed study. Identification of the existence of any specific basking site property that heavily influences site selection will be crucial in guiding the future water level mitigation efforts (see below).

In order to mitigate the effects of habitat loss due to water level changes, I suggest the testing of artificial basking platforms. Work on this research has already begun as a direct result of the information given in this manuscript. A variety of platform designs will be tested in a variety of locations so as to determine preference for physical characteristics and/or placement by basking turtles. The goal is to provide adequate, attractive basking habitat that is available regardless of the nature of the river.

Education of the public is the most effective way to address basking disturbance issues. By making boaters and kayakers aware of the presence of the turtle population and the importance of extended basking time, disturbance rates may decrease. I suggest continuing outreach in the community regarding turtle awareness, particularly those life history stages linked with season, and the placement of informative signage specific to kayakers in the local town and Susquehanna State Park.

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RICHARDS-DIMITRIE, T.M. 2011. Spatial ecology and diet of Maryland endangered Northern Map Turtles (*Graptemys geographica*) in an altered river system: implications for conservation and management. Unpublished M.S. thesis. Towson University, Maryland.

SCHWARZKOPF, L., AND R.J. BROOKS. 1985. Application of operative environmental temperatures to analysis of basking behavior in *Chrysemys picta*. Herpetologica 41:206-212.

SEIGEL, R.A., K.P. ANDERSON, T.M. RICHARDS, AND N. ELLER. 2013. Nesting and Basking Ecology of Northern Map Turtles in the Susquehanna River: Impacts of Human Disturbance and Effectiveness of Mitigation Measures. Interim report, Exelon Nuclear.

SHEALY, R.M. 1976. The natural history of the Alabama Map Turtle, *Graptemys pulchra Bau*r, in Alabama. Bulletin of Florida State Museum, Biological Sciences 21:47-111.

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STEINHAGEN, H.P. 1977. Thermal conductive properties of wood, green or dry, from −40□□to +100□C: a literature review. Gen. Tech. Rep. FPL–GTR–9. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

TEAR, T. H, P. KAREIVA, P.L. ANGERMEIER, P. COMER, B. CZECH, R. KAUTZ, L. LANDON, D. MEHLMAN, K. MURPHY, M. RUCKELSHAUS, J. M. SCOTT, AND G. WILHERE. 2005. How much is enough? The recurrent problem of setting measurable objectives in conservation. BioScience 55:835-849.

VOGT, R.C. 1980. Natural history of the map turtles *Graptemys pseudogeographica* and *G. ouachitensis* in Wisconsin. Tulane studies in Zoology and Botany 22:17-48.

WATERS, J.C. 1974. The biological significance of the basking habit in the black-knobbed sawback, *Graptemys nigrinoda*. Unpublished M.S. thesis, Auburn University, Auburn, Alabama.

Kaite P. Anderson

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Education

GRE Scores: Verbal: 162 (90% below) Quantitative: 149 (49% below) Writing: 4.5

Master of Science, Biology GPA 3.95
Towson University, Towson, MD January 2012- Present

Coursework: Landscape Ecology, Evolutionary and Ecological Physiology, Professional Aspects of Biology, Limnology, Wetlands Ecology, Introductory Statistics: Data Analysis and Interpretation, Multivariate Statistics: Community Analysis and Bioassessment, Advanced Statistics (audit)

Bachelor of Science, Organismal Biology and Ecology, Zoology Concentration GPA 3.74
Towson University, Towson, MD August 2009 – December 2011

Relevant Coursework: General Zoology, Genetics, Animal Behavior, Herpetology, Invertebrate Zoology, Botany, Animal Physiology, Cell Biology, General Ecology, Independent Research, Biostatistics

Associate of Science, General Biology GPA 3.34
Harford Community College, Churchville, MD September 2006-May 2009

Relevant Coursework: General Biology I and II, Anatomy and Physiology, General Chemistry I and II, Organic Chemistry I and II, Physics I and II, Calculus I and II

Research

Primary researcher:

Towson University Master of Science Thesis 2012-Present
Basking habitat selection in endangered Northern Map Turtles, *Graptemys geographica*, in an altered river system: implications for conservation and management

- Conducted under two year Exelon Generation Company Grant

Undergraduate Independent Research 2011
Basking behavior and nesting ecology of Northern Map Turtles, *Graptemys geographica*

Assisted with:

Nesting ecology of Maryland Bog Turtles (*Glyptemys muhlenbergii*) 2013

- Hand collection, radio-telemetry, vegetation surveys

Comparison of aquatic turtle populations in restored versus natural wetlands in Pennsylvania 2013

- Hoop trap collection; mark-recapture

Comparison of Amphibian and fish populations in restored versus natural wetlands on the Coastal Plain of Maryland 2012 - 2013

- Frog call surveys; minnow trap, funnel trap, and drift fence/pitfall trap collection

Snake diversity survey, Harford Glen Center for Conservation Research 2012

- Cover mats; minnow traps; collected morphometric data

Ranavirus sampling at Maryland ICC Box Turtle translocation field site 2011-2012

- Implemented new protocol for water sampling and amphibian monitoring
- Surveyed for incidental infections in Box Turtles
- Continuing on a broader scale in Spring 2014

Experience

Towson University, Teaching Assistant 2014

- Instructor of Zoology laboratory; Ecology, Evolution, Anatomy, and Physiology

Towson University, Teaching Assistant 2014

- Instructor of General Biology laboratory for non-biology majors; Ecology and Evolution

Towson University, Research Assistant 2012 –2013

- Impacts of human recreation and flow regime on basking behavior in Northern Map Turtles
- Nesting ecology of Northern Map Turtles
- Mark and Recapture of hatchling Northern Map Turtles

Towson University, Teaching Assistant 2013

- Assisted lecture, laboratory, and field techniques for Biology 467/567; Herpetology

Harford Glen Center for Conservation Research, Teaching Assistant 2012

- Assisted with primary research conducted by 5^{th}-8^{th} grade students

Towson University Undergraduate Research 2011

- Assisted with nesting ecology of Northern Map Turtles
- Conducted preliminary research on basking behavior of Northern Map Turtles
- Public outreach and education

Laboratory Preparation Technician 2008-2012

- Preparation of lab materials for college biology students
- Care, maintenance, and organization of laboratory equipment
- Care of laboratory animals

General Field/Technology Experience

Mark and recapture; Visible Implant Elastomer administration; radio-telemetry; hoop trap, minnow trap, basking trap use; installation and use of drift fence/pitfall trap arrays; aseptic sampling techniques for amphibian disease; road-cruising; kayaking; boating license; snorkeling; electroshocking; veterinary ultrasound; GPS; GIS; Statistical software: Program R, JMP, EstimateS (diversity statistics)

Volunteer Experience

NorthBay Adventure Camp, outdoor education facility 2014

- Co-developing Map Turtle conservation curriculum to implement on site and in Cecil County Public School system

North American Amphibian Monitoring Project, *Route Volunteer* 2013-Present

- Frog call surveys

Susquehannock Wildlife Society, animal rescue 2013

- Non-profit organization; local outreach and animal rescue

Northern Map Turtle Conservation Education, Port Deposit, MD 2012-Present

Maryland Amphibian and Reptile Atlas, *Block Volunteer* 2012-Present

- Species identification and documentation for Harford and Baltimore Counties, Maryland

Habitat Rehabilitation, Gashouse, Port Deposit, MD 2012- Present

- Preparation for rehabilitated nesting habitat and visitor's center

Maryland Diamondback Terrapin Working Group 2012-Present

Susquehannock Wildlife Society, outdoor education presentations 2012

- General wildlife conservation; field techniques

Camp Counselor, Grade 5, Harford Glen Outdoor Education Center 2004- 2005

Publications and Professional Reports

Anderson, K.P., N.W. Byer, R. J. McGehee, and T.M. Richards-Dimitrie. 2014. A new system for marking hatchling turtles using visible implant elastomer. Herpetological Review (In Press).

Byer, N.W., K.P. Anderson, and R.A. Seigel. 2013. Geographic Distribution: Hemidactylus mabouia (wood slave). Herpetological Review. 44 (2):273.

Seigel, R.A., K.P. Anderson, T.M. Richards-Dimitrie. Effectiveness of Nest Site Restoration for the Endangered Northern Map Turtle. Maryland State Highway Administration, Quarterly Progress Reports. June, September, December 2013.

Seigel, R.A., T.M. Richards, K.P. Anderson, and N.W.Byer. "Nesting and Basking Ecology of Northern Map Turtles in the Susquehanna River: Impacts of Human Disturbance and Effectiveness of Mitigation Measures". Interim report, Exelon Nuclear. November 2012.

Seigel, R.A., T.M. Richards, K.P. Anderson, and S.L. Badolato. "Nesting and Basking Ecology of Northern Map Turtles in the Susquehanna River: Impacts of Human Disturbance and Effectiveness of Mitigation Measures". Interim report, Exelon Nuclear. November 2011.

Presentations

(P = Poster, T = Talk)

Joint Meeting of Ichthyologists and Herpetologists (T) 2014

- Impacts of human recreation and hydroelectric flow regime on basking behavior in Northern Map Turtles, *Graptemys geographica*

Joint Meeting of Ichthyologists and Herpetologists (P) 2014

- A new system for marking hatchling turtles using visible implant elastomer

Towson University, Guest Lecture Biol452: Wetlands Ecology (T) 2013

- Conservation research of endangered Northern Map Turtles

International Sea Turtle Symposium (P) 2013

- Impacts of human recreation and flow regime on basking behavior in Northern Map Turtles, *Graptemys geographica* (Updated)

Exelon Generation Company Luncheon (T) 2012

- Conservation of Maryland's Northern Map Turtles

Harford Glen Center for Conservation Research (T) 2012

- Herpetofauna of Harford Glen

Towson University Student Research Expo (P) 2012

- Impacts of human recreation and flow regime on basking behavior in Northern Map Turtles, *Graptemys geographica*

Susquehanna State Park Camp Fire Program (T) 2012

- Conservation research of endangered Northern Map Turtles

Professional Organizations

Towson University Biology Graduate Student Association, founding member, events coordinator 2014
Susquehannock Wildlife Society 2013-Present
Partners in Amphibian and Reptile Conservation 2011-Present
Society for the Study of Amphibians and Reptiles 2011-Present
Ecological Society of America 2011-Present

Scholarships and Awards

Exelon Generation Company Grant ($35,000-50,000 – TBD) 2014
Maryland State Highway Administration Grant $55,000 2014-2015
Towson University Teaching Assistantship, $8000/year 2014
Towson University Summer Research Support, $4000/year 2012-Present
Towson University Research Assistantship, $8000/year 2012-2013
Phi Beta Kappa Honors Society 2007-2009
Alfred C. O'Connell Honors Scholarship, full tuition 2006-2008