PAINTED TURTLE ECOLOGY IN A FRESHWATER TIDAL MARSH: CONCLUDING SURVEY

A Final Report of the Tibor T. Polgar Fellowship Program

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ABSTRACT

The painted turtle (*Chrysemys picta*) is a common species of freshwater turtle in New York State, but little is known of their ecology and habitat use in tidal wetlands, which are considerably different from their typical, non-tidal habitats. Understanding how painted turtles, and freshwater turtles in general, persist in tidal habitats is especially relevant in the Hudson River Estuary, because it hosts over half of the amphibian and reptile species present in New York State. Habitat use and home range data of turtles in a freshwater tidal habitat were collected over most of the active season in 2018 (April - September) via radiotelemetry. Home range estimates were constructed using the 100% minimum convex polygon method. Microhabitat and tidal zone selection were also assessed. Turtle home ranges from 2018 were compared to data collected from 2015 through 2017, and home range varied significantly among some years. Additionally, turtles selected microhabitat based on tide stage. These data are informative to painted turtle behavioral ecology and may also provide insight into how typically non-tidal species may adapt to tidal conditions.

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INTRODUCTION

The painted turtle (*Chrysemys picta*) is a species of freshwater turtle commonly found throughout the eastern United States and southern Canada (Ernst and Lovich 2009). Typically, these turtles are found in still or slow-moving, fresh water bodies, such as sluggish stream reaches, marshes, lakes or ponds, in often dense populations (Van Dijk 2011; Ernst and Lovich 2009). Due to the species' abundance and wide distribution, painted turtle ecology is well studied, including habitat use in non-tidal ecosystems. Several studies have been conducted assessing painted turtle habitat use and movement patterns, concluding that turtles frequently move long distances (MacCulloch and Secoy 1983) and are capable of homeward orientation (Emlen 1969) in non-tidal habitats.

While painted turtles are most commonly found in slow moving fresh water bodies, they are also common in freshwater tidal habitats (Odum et al. 1984). In this distinct ecosystem, little is known of turtle habitat use or movement. A tidal wetland differs substantially from non-tidal water bodies in a number of ways. The constant fluctuation of water level, contrasting ebb and flow at various times of day, different microhabitat types between tidal zones, and potentially fast-moving currents make a tidal wetland a complex habitat that may require behavioral adaptations for reptiles (Kiviat 1989). Painted turtle ecology has not been studied extensively within a tidal wetland, but previous research conducted in Tivoli North Bay, a freshwater tidal marsh of the Hudson River, has indicated that turtles may be altering behavior in response to tidal conditions (Bacon and Kiviat 2018). The population density of painted turtles in Tivoli North Bay is far lower that what is typically expected in a non-tidal habitat, which may be due to high levels of emigration or mortality (Rozycki and Kiviat 1996). Radiotelemetry analysis has found that painted turtle home ranges in Tivoli North Bay are large and variable among individuals, between 0.04 and 45.44 ha (Bacon and Kiviat 2018). Home range size can serve as a measure of the quality of a habitat (Akresh et al. 2017); however, home range is not well defined for turtles in non-tidal habitats, thus prohibiting comparison with tidal habitats (Ernst and Lovich 2009). The size and variability of home range found in Bacon's 2015 work may indicate some level of patchiness of habitat quality in Tivoli North Bay specifically, or that tidal conditions necessitate movement across long distances. Additionally, reversing tidal currents or fluctuating water levels may disorient turtles. In mammals, home range size has been found to negatively correlate with seasonal resource stability (Viana et al. 2018) and resource abundance (Corriale et al. 2013), indicating that as resources become scarce, home range size increases. Similarly, in bullsnakes (*Pituophis catenifer sayi)*, home range area increases in poor quality habitats (Kapfer et al. 2010). The variation in size of range between individuals, along with low population density, suggest that Tivoli North Bay, and perhaps tidal wetlands in general, are not ideal habitats for painted turtles; however, the presence of turtles in this marsh and other freshwater tidal marshes does indicate that they are able to persist, and so the ways in which they are utilizing microhabitats in the marsh to compensate for potentially non-ideal conditions become of interest.

In a tidal wetland, the constant ebb and flow of water creates a dynamic environment, where the same geographic location can become multiple different habitats over the course of a tide cycle (Swarth and Kiviat 2009). For turtles to be able to properly thermoregulate, forage, reproduce, and avoid predation, it may be necessary to select different microhabitats as tidal conditions induce change in the environment. Eastern box turtles (*Terrapene carolina carolina*) alter habitat selection to prefer non-tidal habitats to tidal habitats when air temperatures are high (Marchand et al. 2004) and red-bellied turtles (*Pseudemys rubriventris*) alter basking behavior in response to water depth and tidal flow (Swarth 2004). Snapping turtles (*Chelydra serpentina*), a species also present in Tivoli North Bay, alter habitat selection in accordance with the tide cycle by using different tidal zones for thermoregulation at different tide stages (Kiviat 1980). Thus, painted turtles may also exhibit similar dynamic habitat selection patterns under tidal conditions. Understanding what microhabitats turtles are selecting, both within the larger home range and over the course of the tide cycle, will help to define habitat requirements within a tidal wetland and contribute to understanding how freshwater animals adapt to estuarine wetlands. In this study, microhabitats were defined as the lower, middle, and upper tidal zones, each occupying a third of the vertical tide range and with vegetation and flooding duration distinct from the others. Discovering that painted turtles are, in fact, altering microhabitat selection based on tidal conditions would be a novel finding for the species, as painted turtles generally live in lentic or sluggish lotic water bodies, and thus would not normally be confronted with constantly changing water levels and fluctuating resource availability on a daily scale. Further, identifying areas of favored habitat within the marsh may help to quantify availability of high-quality habitat, and explain some of the variation in home range size found in Bacon's 2015 work.

In this study, painted turtle home range was quantified, and microhabitat selection was assessed within home range. Environmental variables, such as tide stage and water depth, within microhabitats were considered. The objective of the work was to identify patterns between the microhabitats turtles were selecting and the tide cycle in the marsh, in order to understand how turtles might be altering behavior to persist under tidal conditions. Additionally, home range size and distance travelled per day were quantified, in order to identify changes in activity level over the active season which might be specific to tidal conditions. It was hypothesized that turtles would select microhabitats based on water availability, thus moving into low tidal zones at low tide and high tidal zones at high tide. Turtle activity (measured as mean distance travelled per day) was predicted to decrease as the active season progressed, as activity in other similar species decreases over active season duration (Beaudry et al. 2009; Kiviat 1980).

METHODS

Study Site

Tivoli North Bay is a 150 ha freshwater tidal wetland on the eastern edge of the Hudson River (Figure 1) in Dutchess County, New York. It is bordered by upland forest to the east and the Amtrak railroad and Hudson River to the west. Approximately 24 % of the marsh is composed of tidal creeks and pools (Rozycki and Kiviat 1996). Dominant plants include narrowleaf cattail (*Typha angustifolia*), spatterdock (*Nuphar advena*), arrow arum (*Peltandra virginica*), wild-celery (*Vallisneria americana*), watermilfoil (*Myriophyllum spicatum*), and pickerelweed (*Ponderia cordata*). The mean tidal amplitude is 1.2 m (Kiviat 1980).

Trap and Hand Capture

Turtles were captured for transmitter attachment 5 May 2018 through 22 June 2018. Small hoopnet traps (Promar collapsible minnow traps, size medium) with floats attached were set in areas where painted turtle activity had been previously observed and were checked daily. Traps were baited with canned sardines in soybean oil (Frazer et al. 1990). Environmental variables were not collected for the initial capture of turtles in traps, as tide stage, water level, temperature, and other habitat data are time sensitive, and time of turtle occupancy in the traps was unknown. To capture turtles by hand, mudflats and shallow channels were visually scanned or traversed on foot at low tide. Painted turtles

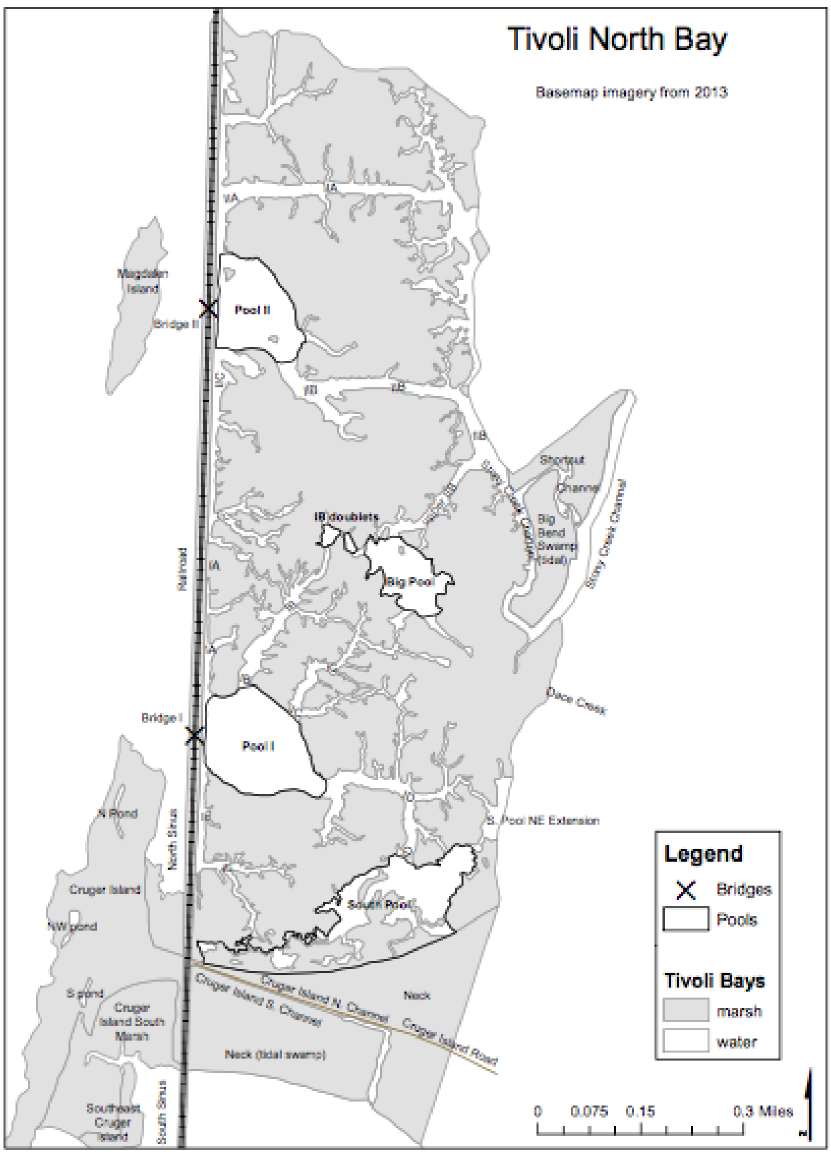

Figure 1.

Topographic map of Tivoli North Bay. The bay is bordered to the west by the Amtrak Railroad, and to the east by upland forest. The total area of the marsh is ~150 ha. ***Map created by Elise Heffernan, Hudsonia.***

were detected on mudflats by a partially exposed carapace or by following turtle footprints in mud. Habitat condition data were collected for individuals caught by hand.

Upon capture, body condition data were collected. Straight line carapace length and plastron length were measured to the nearest millimeter using calipers. Body mass was measured to the nearest gram using a precision spring scale (Pesola) calibrated against digital scales. Turtles were approximately aged by counting scute annuli present on the plastron. Scute annuli can reliably be used to age painted turtles up to 4 years old, after which turtles are considered mature (Stone and Babb 2005). Turtles were examined for anomalous scutes on the carapace and plastron, which included extra scutes or asymmetry, and evidence of predation or other injury, which included missing limbs, pitting, and scars on the carapace and plastron. Turtle sex was identified via body size and anterior claw length. Males can be identified by smaller body size and extended anterior claws (Ernst and Lovich 2009). Maturity of turtles was indicated by size, with turtles having plastron length > 90 mm classified as adults (Ernst 1971). Gravidity of females was determined by palpating for eggs through the soft parts anterior to the hind legs (Wilbur 1975).

Before release, turtles were assigned a unique notch code, which was used for identification upon recapture (Cagle 1939). Turtles were also outfitted with radio transmitter packages (Advanced Telemetry Systems, Isanti, Minnesota), which did not exceed 5% of the turtle's total body weight. To attach the transmitters, two holes were drilled in the 9th and 10th marginal scutes of the turtle's carapace. Bolts were inserted into the drilled holes, and a piece of rubber garage door gasket (approx. 1.5 x 2.5 cm) was placed over the top of the carapace in line with the bolts and secured with two # 8 size nuts and washers. The radio transmitter was attached to the piece of rubber gasket with epoxy putty (Water Weld). Attaching the transmitters in this way was necessary because painted turtles shed entire scutes during molt. In previous years, when transmitters were attached directly to the carapace using only epoxy, scute shedding resulted in detachment of transmitters. Turtles were released in the same location within 24 hours of capture. Individuals are referred to by their radio channel numbers.

Radiotelemetry

Each turtle was tracked via radiotelemetry following release. A Communication Systems receiver (model R-1000) and vinyl-coated antenna (RA-23K, Telonics, Inc) were used to detect signals of nearby individuals. Each transmitter was detectable within a radius of 100 meters. Upon locating a turtle, coordinates were recorded with a Garmin GPS 12. Turtles were tracked approximately once per week for the duration of the study period, between 11 April and 15 August 2018. Individuals that were captured and tagged in 2018, beginning on 5 May, were tracked from the date of capture through 15 August.

Environmental Variable Data Collection

Upon hand capture or radio location, environmental variable data were recorded. Environmental variables included air temperature, water temperature, cloud cover, wind speed (Beaufort scale), vegetation, tidal zone occupied, and water depth. Water depth was a measure of the depth of water in the bay at a given point in the tide cycle measured from the nearest adjacent low tide zone, not the depth of water above the turtle in its tracked location. While tide stage can be used to approximately represent water depth, measuring depth directly controls for fluctuations in water flow due to weather or the lunar cycle. The marsh was divided into three tidal zones: lower, middle, and upper. For this study, the lower tidal zone classification contained mudflats, spatterdock and pickerelweed beds, and, in some cases, shallow subtidal habitats. The lower tidal zone is exposed at the lowest tide stages (spring low tides), including the uppermost subtidal portions of the habitat, which are slightly below Mean Low Water (MLW). The middle tidal zone was the transition area between lower and upper tide zone. This area was at a steep angle (~45 º) in many places, contained sparse vegetation, and was exposed and submerged periodically during the tide cycle. The upper tidal zone consisted of cattail stands on the creek banks and some small, shallow channels deeper in the stands. This zone was only submerged at the highest tide stages.

Statistical Analyses

Turtle home range size was calculated using the 100% minimum convex polygon method (ArcMap version 10) (Powell 2000). The Spearman rank correlation was used to assess the relationship between home range size and body mass, and home range size and number of radio locations. A 95% confidence interval was used to determine differences in home range size between males and females from 2018, and female range size between 2018 and 2015. An unpaired t-test was used to compare body size between 2015 and 2018 females. To identify changes in activity over the course of the season, mean distance travelled per day was calculated by dividing the total distance between two consecutive tracked locations by the number of days that had elapsed between radio locations (Beaudry et al. 2009). The Spearman rank correlation was used to evaluate relationships between activity (measured as mean daily movement), day of year, and air temperature at time of location. Differences in distance travelled per day between males and females were assessed using the Welch two sample t-test. Chi-squared tests and pairwise t-tests were used to determine significance in tide zone selection and tide stage. The Welch two sample t-test was used to determine significance between water level, air and water temperature, and tidal zone selection. Middle tide zone data were eliminated from analysis due to low number of observations ($n=4$). Means are presented $\pm$ SD.

RESULTS

Capture

Sixteen turtles were captured, including four males, ten females, and two juveniles. One female (# 29) was a recapture from 2015, as detected from her notch code. Seven turtles were caught by hand and seven were caught in traps. The mean and SD of turtle masses were: females (n=10), 436.5 ± 99.8 g; males (n=4), 298.8 ± 94.2 g; and juveniles (n=2), 71.5 ± 12.0 g. The mean carapace length (CL) and plastron length (PL) of turtles were: females, 150.7 ± 12.8 mm (CL) ,140.5 ± 12.3 mm (PL); males, 135.6 ± 15.6 mm (CL), 122.8 ± 16.2 mm (PL); juveniles, 75.5 ± 2.1 mm (CL), 69 ± 3.0 mm (PL) (Table 1).

Table 1. **Mass, carapace length (CL) and plastron length (PL) values of captured turtles.**

	Female	Male	Juvenile
Number	10	4	2
Mass (g)	436.5 ± 99.8	298.8 ± 94.2	71.5 ± 12.0
CL (mm)	436.5 ± 99.8	135.6 ± 15.6	75.5 ± 2.1
PL (mm)	140.5 ± 12.3	122.8 ± 16.2	69 ± 3.0

Inter-year Comparison of Body Size

Body mass of females did not differ between 2015 (468 ± 68.5, n=9) and 2018 (436.5 ± 99.8, n=10, p=0.44, unpaired t-test). Female carapace length also did not differ between years: 2015 (150 ± 7.7, n=9); 2018 (150.7 ± 12.8, n=10, p=0.91, unpaired t-test). Body size was not compared between years for males due to small sample size.

Predation and Scute Anomaly

Evidence of predation attempts or infection (scars, pitting) were detected on nine of the 14 captured turtles. Two of the turtles had missing limbs: a female missing both front feet, and a male missing the left front foot. There was also a high incidence of scute anomaly. Out of 18 captures, five turtles had anomalous scutes, two turtles had 13 marginal scutes on both sides of the carapace, and three turtles had asymmetrical carapacial scutes.

Home Range Size

Sixteen turtles were tracked in 2018. Fourteen were adults captured in 2018, and two were females tagged in 2017 with active transmitters. Turtles were each tracked 4-17 times over the study period. Variation in the number of radio-locations was due to differences in when transmitters were attached (turtles that were captured earlier in the season had more radio-locations), and difficulty consistently locating some individuals due to the large expanse of marsh with limited canoeable channels. Turtles that had been previously tagged during 2017 were inconsistently located after June, indicating that their transmitters lost function. Data from these individuals were excluded from home range analyses, in order to assess activity over the entire duration of the active period. Data from these individuals were included in comparisons between mean daily movement and date, and habitat selection analyses. The mean number of radio-locations for an individual was 9.3. The mean home range size was 5.25±5.35 ha. For males (n=4), the smallest home range was 1.75 ha, the largest was 20.48 ha, and the mean was 8.04 ± 8.47 ha. For females (n=10), the smallest home range was 0.04 ha, the largest was 11.59 ha, and the mean was 4.14 ± 3.55 (Tables 2 and 3). The number of times an individual was located was not significantly correlated with the home range size (rho=0.358, p=0.172, n=14). The one female recapture (# 29) had a home range area of 11.59 ha, which was larger than her home range area of 1.76 ha in 2015 (Bacon and Kiviat 2018). Interestingly, this turtle's geographic range was within the same region of the marsh between years.

Home range size was not significantly correlated with carapace length for males (rho= -0.6, p=0.42, n=4) or females (rho=-0.2, p=0.58, n=10). Male home range size was not significantly different from female home range size (95% CI: males: 1.07-15.06; females: 2.29-5.47). Female home ranges were compared using historic tracking data from 2015-2018. Female home ranges from 2015 (n=7) were significantly larger than female home ranges from 2018 (n=10) (95% CI: 2015:15.28-29.21; 2018: 2.29-5.99, Figure 4). Home range data collected during the intervening years (2016, 2017) were also compared. Female home range was smaller during 2016 (n=16) compared to 2015 (n=7) (95% CI: 2016: -6.33-7.599, 2015:15.28-29.21). There was no significant difference found between female home range size in 2017 (n=3) and any other year (95% CI: 2017: 3.62-17.56). Male home range size between 2015 and 2018 was not assessed due to lack of male tracking in 2015.

Table 2. Mean home range areas for female and male turtles.

	Mean (ha)	Minimum (ha)	Maximum (ha)
Total Sample	5.25±5.35	0.04	20.48
Females	4.14 ± 3.55	0.04	11.59
Males	8.04 ± 8.47	1.75	20.48

Table 3. **Individual home range values. Individuals are identified by their radio channel numbers (30-46), and . sorted in order of increasing size.**

Turtle	Range (ha)	Sex
40	0.04	Female
41	0.09	Female
43	0.91	Female
36	1.75	Male
42	3.10	Female
46	3.13	Female
30	3.99	Male
31	4.93	Female
32	5.03	Female
44	5.31	Female
34	5.96	Male
45	7.26	Female
29	11.59	Female
33	20.48	Male

Distance Travelled Per Day

The mean distance between tracked locations was 203.9 ± 340.4 m, and the mean number of days between radio locations was 8.2 ± 5.6. The hypothetical mean distance travelled per day was: 33.2 ± 60.9 m for all turtles, 40.9 ± 63.0 m for males, and 30.9 ± 60.4 m for females. The maximum distance calculated was 534.0 m (a female), and minimum was 0.32 m (also a female). Mean distance travelled per day did not differ significantly between males and females (p=0.44, t=0.78, df=48.142, n=132). There was no correlation between day of year (Julian date) and distance travelled per day, though the longest distances travelled did occur later in the season (rho=0.112, p=0.197, n=132, Figure 5).

Tidal Zone Selection

Each time a turtle was located, tidal zone and tide stage were recorded. The proportion of turtles occupying upper and lower tidal zones changed significantly with some tide stages (x^2=33.398, p=0.0025, df=14, n=151). Middle tidal zone data were eliminated from analyses because very few turtles were found in this zone (n=4). Turtles chose the upper tidal zone significantly more often during high tide than during low tide (p=0.0001) or late ebb tide (p=0.0206). Turtles chose the lower tidal zone significantly more frequently during low tide than during mid-flood (p=0.036) or high tide (p=0.0001, n=151, pairwise t-test, Bonferroni adjustment, Figure 6, Table 4)

Water depth (independent of the direction of movement of water in the marsh) was also considered. Turtles chose the low tidal zone when water levels were lower, and the high tidal zone when water levels were higher (p=0.0026, t=-3.0634, df=133.88, n=141, Welch two sample t-test, Figure 7). Water temperature (p=0.99, t=-0.0005, df=141.82, n=147) and air temperature (p=0.457, t=-0.746, df=136.03, n=147, Welch two sample t-test) were not significantly different between upper or lower tidal zone selection.

Table 4. P-values of tidal zone selection comparisons between tide stages (pairwise t-test with Bonferroni adjustment). Significance indicated with an asterisk. Tide stages that are significantly different from one another (*) have different proportions of turtles utilizing the upper vs lower tidal zone.

	Low	Early Flood	Mid Flood	Late Flood	High	Early Ebb	Mid Ebb
Low	-	-	-	-	-	-	-
Early Flood	1.000	-	-	-	-	-	-
Mid Flood	0.036*	1.000	-	-	-	-	-
Late Flood	0.3257	1.000	1.000	-	-	-	-
High	0.0001*	1.000	1.000	1.000	-	-	-
Early Ebb	0.7928	1.000	1.000	1.000	1.000	-	-
Mid Ebb	1.000	1.000	1.000	1.000	1.000	1.000	-
Late Ebb	1.000	1.000	1.000	1.000	0.0206*	1.000	1.000

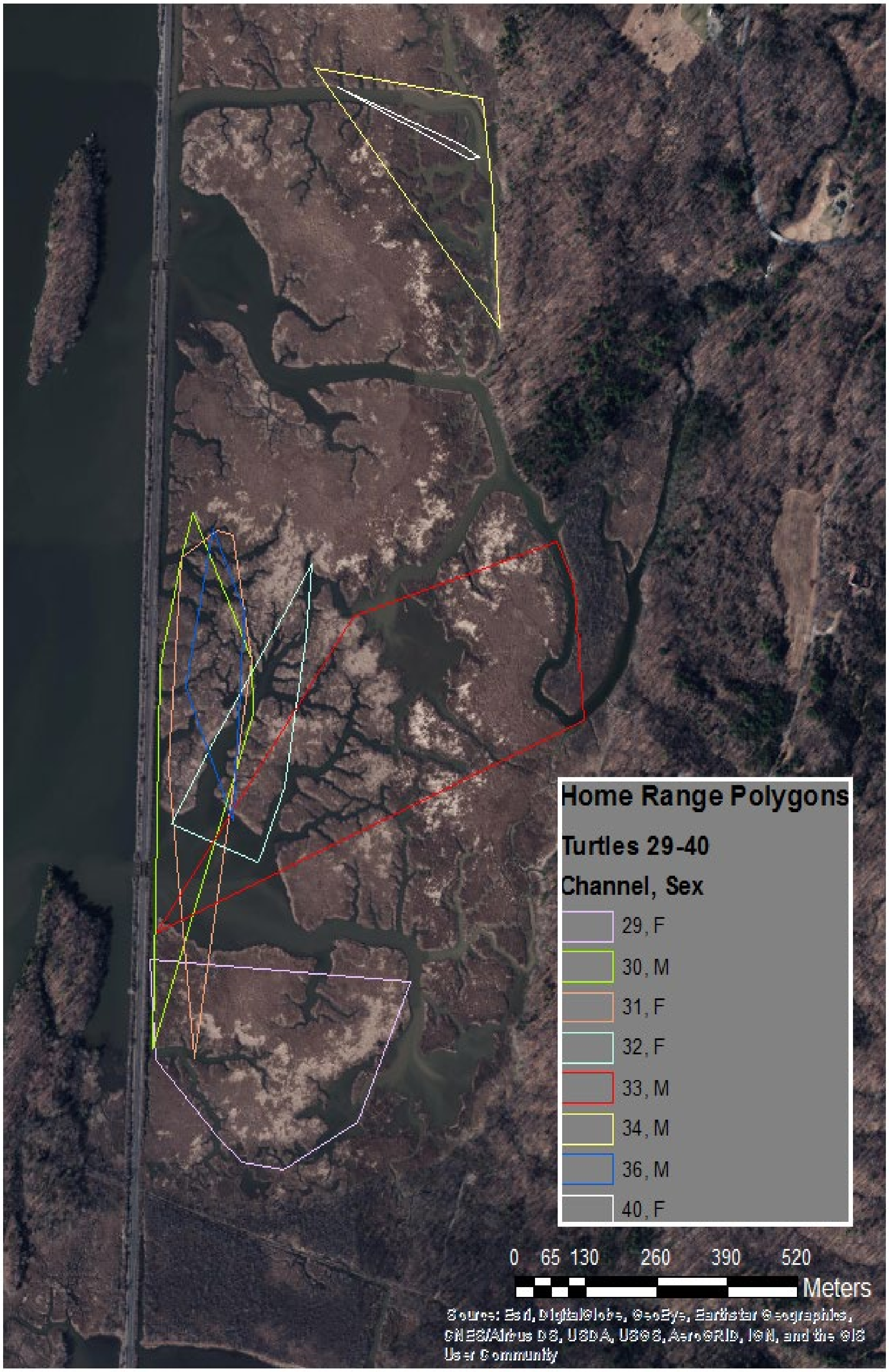

Figure 2 . **Home range map for turtles 29-40. Individual turtles are represented by different colors.**

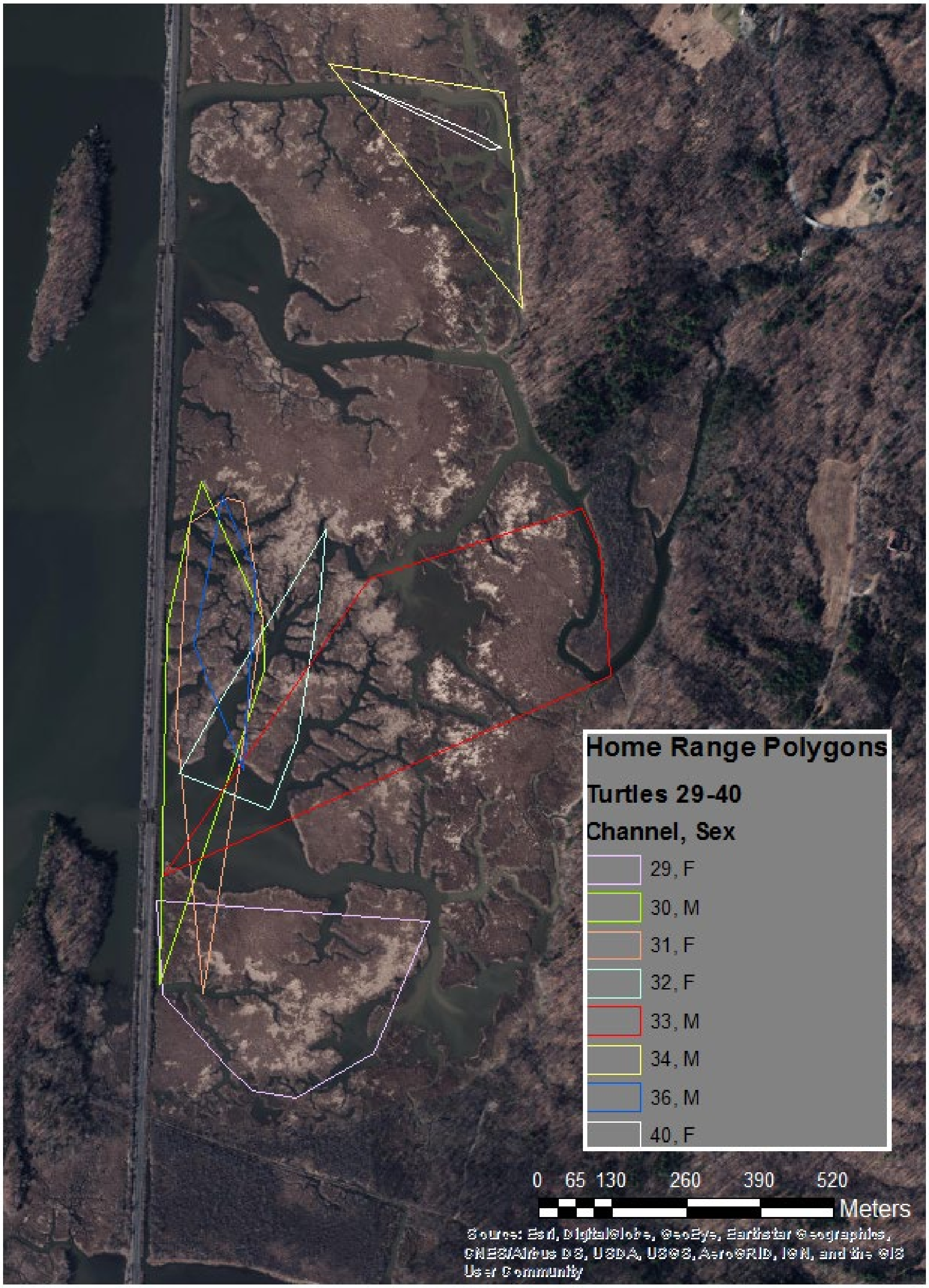

Figure 3: Home range map for turtles 41-46. Individual turtles are represented by different colors.

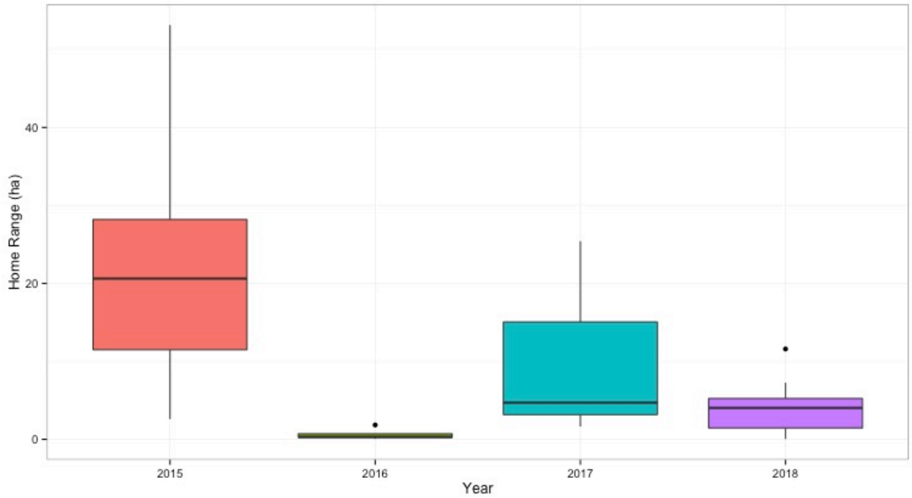

Figure 4. **Inter-year comparison of home range values. Boxplots compare home range of females tracked from 2015 through 2018. (Bold line=median, box upper= third quartile, box lower= first quartile, whiskers = minimum and maximum range values, dots = outliers. Female home ranges were significantly smaller during 2018 (n=10, 95% CI: 2.29-5.99) and 2016 (n=4, 95% CI: -6.33-7.60) compared to 2015 (n=7, 95% CI:15.28-29.21). Home ranges from 2017 did not differ significantly from any other year (n=3, 95% CI: 3.62-17.56).**

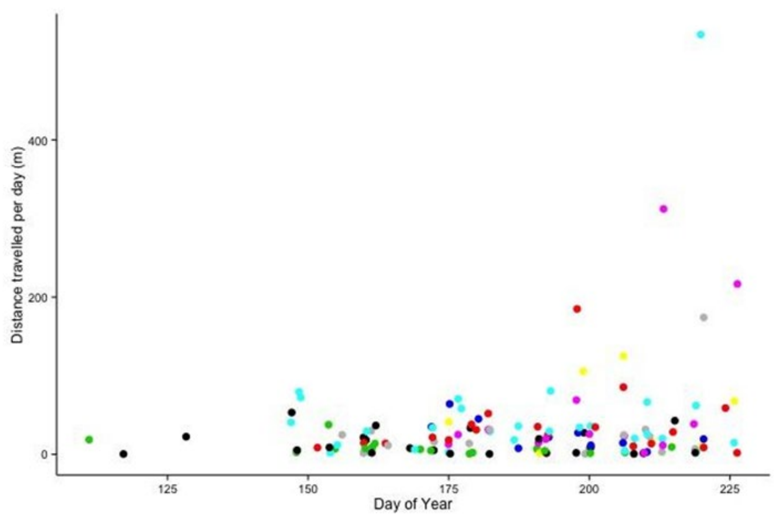

Figure 5. **Correlation between mean daily movement and Julian date. Mean daily movement is defined as the distance between two subsequent tracked locations, divided by the number of days elapsed between radio locations. Colors represent individual turtles. Length of mean daily movement (m=33.2±60.9) did not change over time (p=0.197, rho=0.113, n=133).**

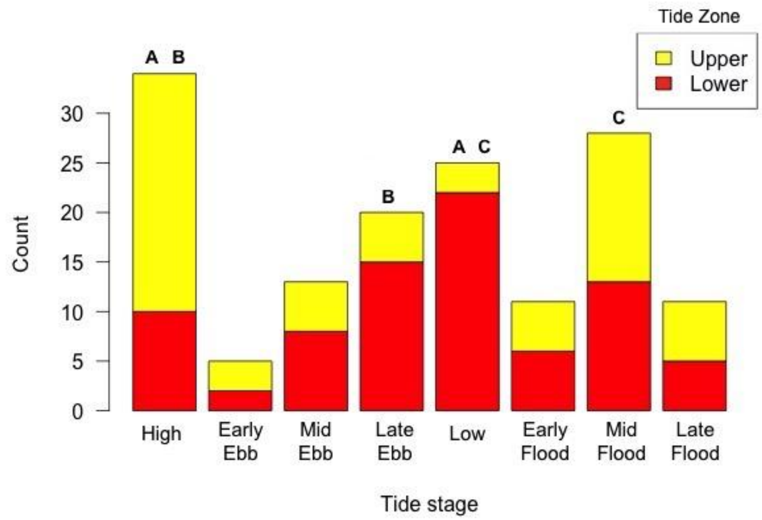

Figure 6. **Tide zone selection across tide stages. Upper tidal zone selection is depicted in yellow, lower tidal zone selection in red. Letters on bars represent significance relationships. Zone selection was significantly different between low and high tide (A), high and late ebb tide (B), and low and mid flood tide (C).**

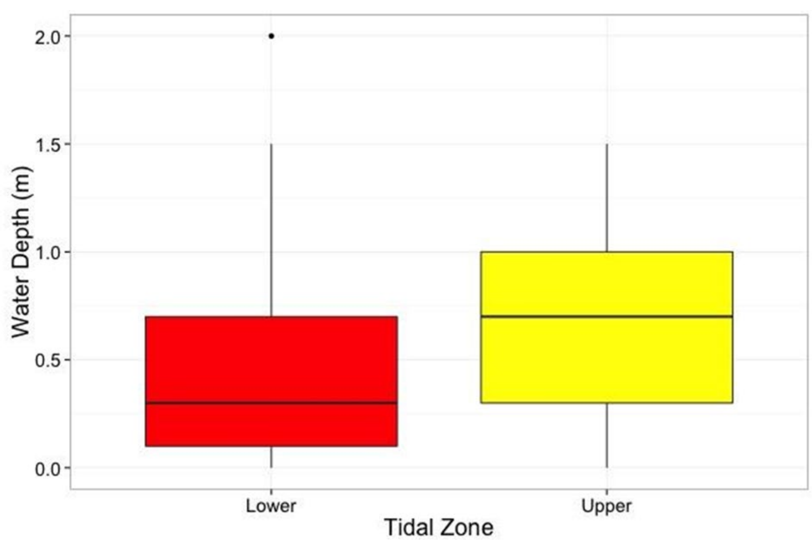

Figure 7. **Comparison of mean water depth between tidal zone selections. Bold line= median, box upper= third quartile, box lower= first quartile, whiskers = minimum and maximum range values, dots = outliers. When turtles chose the upper tidal zone (yellow), mean water depth was higher, and when turtles chose the lower tidal zone (red), mean water depth was lower (p=0.0026, t=-3.0634, df=133.88, n=141, Welch two sample t-test).**

DISCUSSION

From this survey, it is apparent that turtle home range size is highly variable among individuals, and between years. The persistence of turtle #29 within the same general area of the marsh 2015-2017 indicates that at least some individuals do have a sense of direction and "home" within a larger ecosystem. The difference in home range for this individual was 11.59 ha in 2018 and 1.76 ha in 2015 (Bacon and Kiviat 2018). However compelling the behavior of turtle #29 may be, the behavior of one turtle may not be used to draw conclusions about the overall quality of the marsh.

Generally, the mean home range size of individuals was smaller and less variable during 2018 (4.14 ± 3.55 ha) than during 2015 (14.57 ± 15.94 ha), and home range can fluctuate between consecutive years (Figure 4). Most home range polygons included a number of different habitat types, including lower intertidal spatterdock beds, upper intertidal inter-creek cattail marsh, and intertidal and subtidal pools and creeks (Figures 2 and 3). The smaller home range found during 2018 compared to 2015 may indicate that the marsh has increased in habitat quality (Kapfer et al. 2010; Viana et al. 2018). Estuaries are especially dynamic systems and food, or another factor could have changed. The conflicting results of decreased mean range size for the population but increased range for an individual (#29) found between 2015 and 2018 indicate the need for further home range analysis work. In this system, an inter-year comparison of home range for each individual, rather than mean home ranges, might be more valuable for identifying annual fluctuations in habitat quality. While home range size decreased significantly, which may indicate higher resource availability, mean turtle mass did not differ significantly between 2015 and 2018; however, turtle biomass does not necessarily correlate with productivity of an ecosystem (Iverson 1982), and so other indicators of habitat quality, such as vegetation productivity or prey availability, should be considered in future work. An assessment of patchiness of low and high quality habitat between years and seasonally within a year may also help to explain some of the variation in home range size and long distance forays.

Neither sex nor body size was a significant predictor of home range. While mean male home range (8.04 ha) was larger than the mean female home range (4.14 ha), these values for each group were not significantly different from each other. Similarly, male painted turtles have been found to travel farther than female painted turtles in a river, and so a larger sample size may reveal differences in home range based on sex (MacCulloch and Secoy 1983). Home range size was positively correlated with number of radio locations, though not significantly (rho=0.358, p=0.172, n=16).

The goal of identifying microhabitats within home range was to determine what microhabitats within the larger ecosystem were necessary to turtles, and how turtles might be altering behavior in response to tidal conditions. Within the marsh, the microhabitat distinctions considered were between lower, middle, and upper tidal zones. Turtles most often occupied upper and lower tidal zones, and more interestingly, preferred different tidal zones at different stages of the tide cycle. Turtles chose the lower tidal zone over the upper tidal zone at low tide, and the upper tidal zone over the lower tidal zone at high tide. Further, when mean water level was considered, separate from tide stage and direction of water movement, turtles more frequently chose the upper tidal zone when more water was available, and the lower tidal zone when water levels in the marsh were lower. Few turtles were found in the middle tidal zone, perhaps because this area was steep and did not offer much surface area in the parts of the marsh where turtles were tracked. It is novel that turtles are moving between two very different lower and upper tidal zone microhabitats and taking advantage of each based on the availability of water, especially when the more homogenous nature of their typical, non-tidal habitat is considered. This behavior may be serving a similar function to tidal movements made by snapping turtles, in which individuals have been found to move from upper tidal zones to lower tidal zones as water flows out of the habitat, and the reverse as the tide turns (Kiviat 1980). If turtles did not appear to show differentiation of tidal zone selection, and instead occupied the lower tidal zone at all water depths and tide stages, then it may be inferred that they are not adapting behavior to a tidal habitat. Movement between intertidal zones is not required in a non-tidal wetland (for obvious reasons), and so the alteration of habitat selection behavior indicates adaptation necessary to persist.

While knowing that turtles are using each tidal zone and altering selection of the tidal zone based on tide stage, it is unclear what exactly is driving the turtles to move between the upper and lower zones. In the lower tidal zone, turtles have access to benthic prey objects and aquatic vegetation, and do not risk aerial exposure as the tide flows out of the marsh. The upper tidal zone, however, is distinct from the lower tidal zone both in its elevation, period of submergence, and vegetation (and presumably prey options). Painted turtles are generalist foragers, with a diet including macroinvertebrates and vegetation (Ernst and Lovich 2009). The seeds of spatterdock have been found to be an important component of painted turtle diets, along with invertebrate prey (Padgett 2010). Spatterdock is abundant in the lower tidal zone, which does not explain occupancy of the upper tidal zone; however, as spatterdock seeds are only seasonally available, turtles may have to change foraging strategies based on food availability. Arrow arum, a plant common in the middle and upper tidal zone in Tivoli North Bay, has been found in the snapping turtle diet (Lagler 1943), and so it is not unlikely that painted turtles may also be utilizing it. Dietary analysis of painted turtles should be conducted to determine if turtles may be harvesting some prey from upper tidal zone vegetation. The upper tidal zone may also assist turtles in making more direct movements between different areas of the marsh, rather than navigating a long series of winding lower tidal zone channels. Additionally, the upper tidal zone does contain shallow channels, which may provide refuge from predators and competition, such as snapping turtles, which are mainly benthic dwellers.

Although sample sizes are small, the high proportions of scars and anomalous scutes suggest that North Bay may be a stressful environment for painted turtles. Scars that resemble scratches were probably teethmarks from mammalian predation attempts, and the most likely predator is the raccoon (*Procyon lotor*), the population of which has increased greatly in the Hudson Valley during the past fifty years. Anomalous scutes indicate developmental stress that could be caused by environmental contaminants (Bell et al. 2006)

Turtle activity did not decrease with the progression of the active season. For some individuals, activity (measured as mean daily movement) increased, though not significantly (Figure 5). Spotted turtles and Blanding's turtles both exhibit a distinct pattern of seasonal activity, with activity peaking in early summer and falling in late summer (Beaudry et al. 2009). The stability of activity levels through the summer in Tivoli North Bay poses interesting questions about the energy requirements necessary in a tidal wetland, or the overall habitat quality of Tivoli North Bay. Future work to assess activity over the active period might include higher sampling effort and sampling though late summer and fall, to determine a definite “end” to activity. A necessary next step may be to create an index of what a “high quality” habitat is, in order to determine if the behaviors exhibited by this population can be due to the tidal nature, low quality resource availability, or both.

Additionally, the ability of painted turtles to alter behavior significantly is an indication of the adaptability of the species and provides insight into their behavioral ecology. While this study did not provide a definitive home range area for individuals, the continued variability in home range size between individuals and years does pose further questions about the quality of the habitat, or painted turtle ecology in general.

Although the painted turtle is not a species of conservation concern, studying the habitat requirements of a freshwater turtle in a tidal ecosystem can provide a framework for the future conservation efforts of other, less common freshwater turtle species, such as the eastern red-bellied turtle (*Pseudemys rubriventris*) or the spotted turtle (*Clemmys guttata*), in tidal wetlands. It is not uncommon for a species’ distribution to include both tidal and non-tidal wetlands, and so this work assessing adaptations to a tidal existence may be the first step in characterizing larger scale adaptive behavior (Swarth and Kiviat 2009). Understanding how organisms interact with tidal conditions, and how habitat requirements may change in tidal conditions, will be critical to effective conservation (Breisch 2011). Additionally, the changing availability of freshwater tidal marsh habitat in the face of climate change must be considered. As climate change results in rising sea levels, freshwater tidal marshes will be especially at risk due to habitat loss and increased salinity, and so understanding how species are currently utilizing freshwater marshes will help predict the impact of habitat loss in the future (Barendregt and Swarth 2013).

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