ECOLOGY OF PAINTED TURTLES IN A FRESHWATER TIDAL MARSH, TIVOLI NORTH BAY, NEW YORK

A Final Report of the Tibor T. Polgar Fellowship Program

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ABSTRACT

A radiotelemetry study was carried out in 2015 in Tivoli North Bay, a large freshwater tidal marsh in upstate New York and a component of the Hudson River National Estuarine Research Reserve (HRNERR). From mid-May to Mid-August, 13 painted turtles (*Chrysemys picta*) were hand-caught and nine of them were radio-tagged. Their movements were recorded and their home ranges were estimated. Data on carapace length (CL), plastron length (PL), mass, and body condition (e.g., presence of scars, leeches, and carapacial algae) were collected. These data were compared to data taken on the same population in 1995. Plastron length, carapace length, and body mass were not found to be significantly different between the two studies. Home ranges were variable, but overall greater than expected for adults. Juveniles had significantly smaller home ranges than adults. Little aerial basking behavior was observed. There have been few recaptures, suggesting high rates of immigration and emigration, a large population, or unusually low lifespans of tidal marsh painted turtles compared to other populations of painted turtles. If true, these may be due to pollution, predation, or the tidal nature of the bay.

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INTRODUCTION

Many stresses upon turtle taxa are contributing to worldwide population declines. Pesticide use, habitat destruction, collection for food and for the pet trade, and vehicular traffic are among a multitude of factors contributing to the decline in numbers (Ernst and Lovich 2009). The ecology of a population of painted turtles in Tivoli North Bay was studied for three months in spring and summer 2015. The previous research on this population of turtles indicated an unusually low density (Rozycki and Kiviat 1996). The Hudson River is contaminated with PCBs (EPA, n.d.), PAHs (Moret et al. 2007), and heavy metals (Huan et al. 1998). A demographic model indicated adverse impacts of PCBs on snapping turtles at PCB levels comparable to those in the Hudson River (Salice et al. 2014). It is not known if painted turtles are similarly affected by PCBs. PAHs cause lethal and non-lethal deformities in painted turtles, which may be affecting population size (Moret et al. 2007). The present study was motivated by the apparent low density of turtles in the bay and the lack of published data on tidal wetland populations.

The painted turtle (*Chrysemys picta)* is a widespread freshwater turtle found across North America. Its four subspecies are distinguished by morphology and correspond to regions of the United States (Ultsch et al. 2001), (see cnah.org regarding elevation of the southern painted turtle, *Chrysemys picta dorsalis,* to a full species). The painted turtle is a small, opportunistic omnivore with a smooth olive or brown carapace, and red and yellow markings on the edge of its shell. Its diet varies widely based on habitat, consisting of seeds, worms, insects, fish, and crustaceans (Ultsch et al. 2001). Although *C. picta* is probably the best-studied of freshwater turtles, there are few data on tidal marsh populations. Tivoli North Bay painted turtles were measured and marked opportunistically by Erik Kiviat and students in the 1970s, and there was a 1995 study on the same population (Rozycki and Kiviat 1996). Home ranges for adult painted turtles were not expected to be different than home ranges estimated in the literature, nor were significant differences expected between the populations throughout the three time periods in terms of body size or body condition.

MATERIALS AND METHODS

Study Site

Tivoli North Bay, a component of the Hudson River National Estuarine Reserve (HRNERR), is a 154 ha freshwater tidal wetland on the Hudson River in Dutchess County, New York. It contains a network of tidal channels and pools, with two western openings to the main river under two bridges and the remainder of the west side bordered by an Amtrak railroad. Tides are bimodal with a mean range ca. 1.2 m (Kiviat 1980).

The bay's vegetation is primarily narrowleaf cattail (*Typha angustifolia)*, while other important plants include water celery (*Vallisneria americana*), pickerelweed (*Ponderia cordata*), spatterdock (*Nuphar advena*), wild rice (*Zizania* sp.), and purple loosestrife (*Lythrum salicaria*) (Kiviat 1980, NYSDEC 2015). Tivoli Bays habitats include "intertidal marsh, subtidal shallows, mudflats, tidal swamp and mixed forest uplands" (NYSDEC 2015). Potential predators of *C. picta* (Ernst and Lovich 2009) in and around the bay include snapping turtles (*Chelydra serpentina*), great blue herons (*Ardea herodias*), bald eagles (*Haliaeetus leucocephalus*), ospreys (*Pandion haliaetus*), northern harriers (*Circus cyaneus*), and raccoons (*Procyon lotor*) (Observation, Summer

2015). Eggs and young turtles are especially vulnerable to predation (Ernst and Lovich 2009).

Captures

Field work was carried out from 13 May to 19 August 2015, with 4 – 6 hour long days. Five floating hoop traps baited with fish were set in mid-May in channels that turtles were known to frequent. Snapping turtles were caught nearly every day, but no painted turtles were caught. In late June, the traps were removed. In early July, a floating metal box trap was set in a channel where a number of painted turtles had been observed, but that trap likewise caught nothing.

Binoculars and the naked eye were used to search for painted turtles and their tracks along banks, in mudflats, and in channels. Mudflats were inspected both visually and by probing the mud with a canoe paddle. Captures are hereafter referred to as either trap captures or hand captures, which include captures using a dipnet. Six gravid female turtles were captured on their nesting habitats along the railroad that formed the western border of North Bay, and one additional gravid female on the eastern shore of the bay, ca. 1600-2100 h EDT; painted turtles usually nest between 0500-0900 and 1600-2300 h (Mahmoud 1968). However, only five of the six females captured along the railroad were radiotagged.

The 2015 data were compared with previous studies on the same population. The 1970s data were collected April through November by Erik Kiviat and students (Kiviat, unpublished). The 1995 data were collected April through June by Chris Rozycki and Denise Edelson (Rozycki and Kiviat 1996). The 2015 data were collected May through August by Reminy Bacon, assisted by Erik Kiviat, Alexander Graf, John Carroll, Taylor

Cantrall, Gabriella DiGiovanni, Nick Muehlbauer, and Patrick Baker. Turtles were not radiotracked prior to 2015, but data collection was otherwise similar in all three periods.

Data Collection

Turtles were usually processed within an hour of capture. Mass was recorded to the nearest 5 g with a Pesola precision spring scale. Maximum carapace length (CL) and plastron length (PL) were measured to the nearest millimeter with Haglof Mantax calipers held perpendicular to the carapacial midline.

Maturity was determined by CL, which is at least 70-95 mm in adult males, and 97-128 mm in adult females (Ernst and Lovich 2009). Sex was determined by inspecting the front claws of the turtle, which are twice as long in adult males as in adult females, and by palpating for shelled eggs through the soft skin anterior to the hind legs (Wilbur 1975).

The carapace of each turtle was marked with a unique code by filing notches in two or three of the marginal scutes. This method has been used for over 70 years and is not known to significantly injure the turtle. Notch codes are permanent on all but the youngest individuals (Cagle 1939). The first two turtles tagged with radio transmitters were brought back to the Bard College Field Station for observation before release the following day, but the remaining turtles were released within an hour of their capture. Turtles were released within a few meters of the captures site with one inadvertent exception (see Results).

Radiotelemetry

Radio transmitters (Advanced Telemetry Systems, Isanti, Minnesota) were attached to the posterior carapace with WaterWeld™ Epoxy Putty (Model Number 8277, J-B Weld, Sulphur Springs, Texas). The first four turtles caught were given 16.4 g transmitters with a range of ~600 m and the next five were given 3.4 g transmitters with a range of ca. 200 m. Each transmitter package weighed less than 5% of the turtle's mass. A Garmin GPS 12 instrument and an Android HTC One "GPS Essentials" application were used interchangeably to obtain UTM coordinates for the turtle's location. The original capture points of the six females first found on nesting habitats were omitted from home range estimates because the nesting migration is a foray out of the summer home range.

Data Analysis

Student's *t*-test was used to compare the 1995 and 2015 female mass, PL, and CL. Too few males or juveniles were caught in 2015 for analysis. ANOVA was used to compare natural log-transformed CL and PL between males and females in the three periods. ANCOVA was used to compare masses with CL as a covariate. Alpha was set at 0.05 for all statistical tests. A chi-squared test was used to compare the number of missing appendages between the 1970s and 1995 (Table 3). Boxplots show median, quartiles, minimum, and maximum, with asterisks indicating outliers. All statistical and graphical analyses were generated with Minitab version 17 or Statistica version 12.

Distance from nest habitat to first telemetry location was measured using Google Earth Pro. Radiotelemetry points were used to calculate 100% minimum convex polygon home range for each individual using the Minimum Bounding Geometry Tool, "convex hull" geometry type, in ArcGIS 10.3.

RESULTS

Recapture Rate

No turtles marked in previous years were recaptured in 2015. As female painted turtles can live up to 60 years (Ernst and Lovich 2009), this is somewhat surprising. The low recapture rate may be due to a low sampling effort, turtles in tidal marshes may have much shorter life spans compared to non-tidal populations, or there may be high levels of immigration and emigration in the study area.

Catch per Unit Effort

Catch per unit effort (CPUE) for hand-captured turtles for each two-hour search on the railroad nesting habitat was about one turtle/search. During the 25 days of field work, six turtles were hand-caught in nesting habitat and six were hand-caught in the marsh (the last one, turtle 2, was captured in the parking lot of North Bay's boat landing at the end of the Kidd Lane). CPUE for hand captures in the marsh was 0.24/day. In the marsh, an average of three hoop nets captured 0.00 turtles during the 21 days; total number of hoop net days was 63. The box trap was set in the bay for 25 days and captured 0 turtles.

Population Structure

All turtles included in the data analysis were captured by hand (Table 1). Too few turtles were caught to estimate population structure. Most turtles were captured in the female-exclusive nesting habitat, resulting in sex bias for hand-captured turtles. The ratio of total adult males to total adult females caught is 1:4. The ratio of males to females caught only in the marsh is 2:1. The ratio of juveniles to adults captured is 3:11.

Male	Female	Juvenile	Hand-captured	Trap-captured
2	9	3	14	0

Table 1: Sexes and capture methods of all turtles captured in 2015.

Body Condition

The body condition indicators of captured turtles are summarized in Table 2. No turtles had missing claws or feet, but otherwise every juvenile and female had at least one body condition abnormality. Boxplots were constructed illustrating the distribution of CL, PL, and mass (Figs. 1-3).

Across the three time periods, the differences between CL (F = 1.690, p = 0.188) and PL (F = 1.960, p = 0.146) were not statistically significant. There was a significant difference between sexes for CL (F = 16.17, $p < 0.05$) and PL (F = 20.76, $p < 0.05$). When the natural log of CL was controlled for in an ANCOVA, mass was not significantly different across time periods (F = 1.630, p = 0.202) or sex (F = 1.650, p = 0.202).

The Spearman rank correlation of the home range estimates and the number of times tracked (n) is not significant (r = 0.264, p = 0.493), indicating that the number of times tracked had little influence on the home range estimates. No significant differences were found between numbers of missing appendages in the 1970s and 1995 ($p > 0.05$).

	Anomalous Scutes	Scars	Teeth marks	Leeches	Algae	Missing Claws	Missing Feet
Males (n=2)	0	2	1	1	2	0	0
Females (n=9)	5	6	2	4	5	0	0
Juveniles (n=3)	1	2	2	2	2	0	0

Table 2: **The male, female, and juvenile turtles captured in 2015 showing numbers of turtle with body condition indicators. Teeth marks are believed due to predation attempts by raccoons or other mammals; scars are from non-predator damage to the shell.**

Year	**1970s**	**1995**
Sample Size (N)	132	21
Missing Appendages	6	0

Table 3: **Comparison between the missing appendages of the 1970s turtles and the 1995 turtles.**

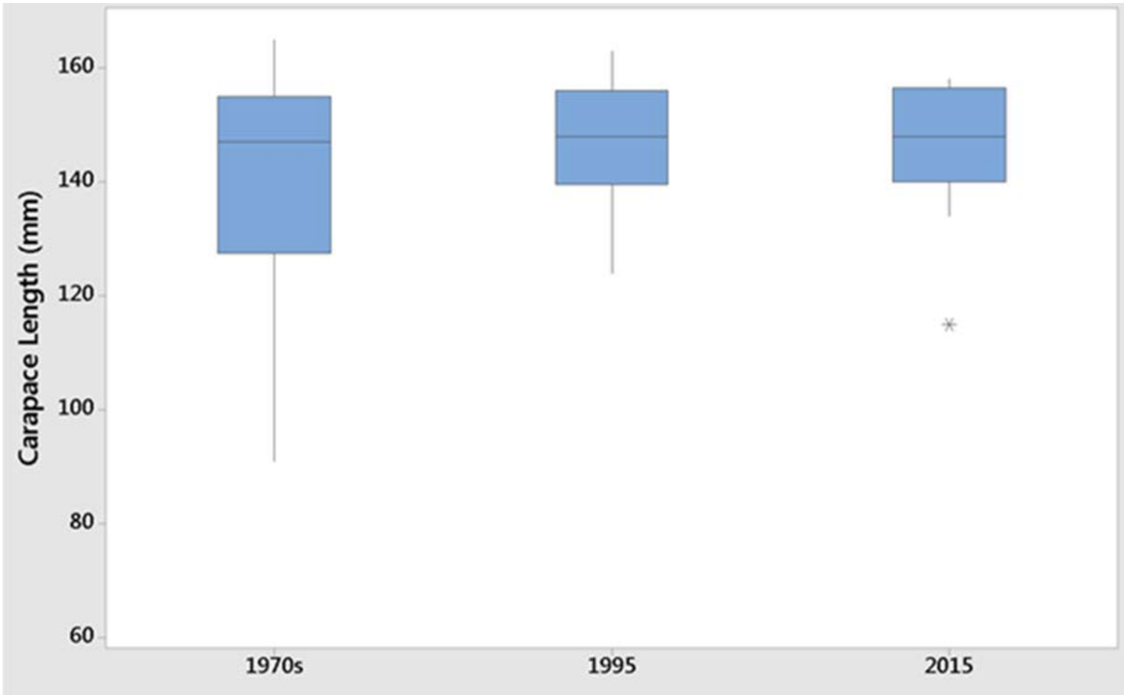

Figure 1: Boxplot of Female Carapace Lengths in the 1970s, 1995, and 2015.

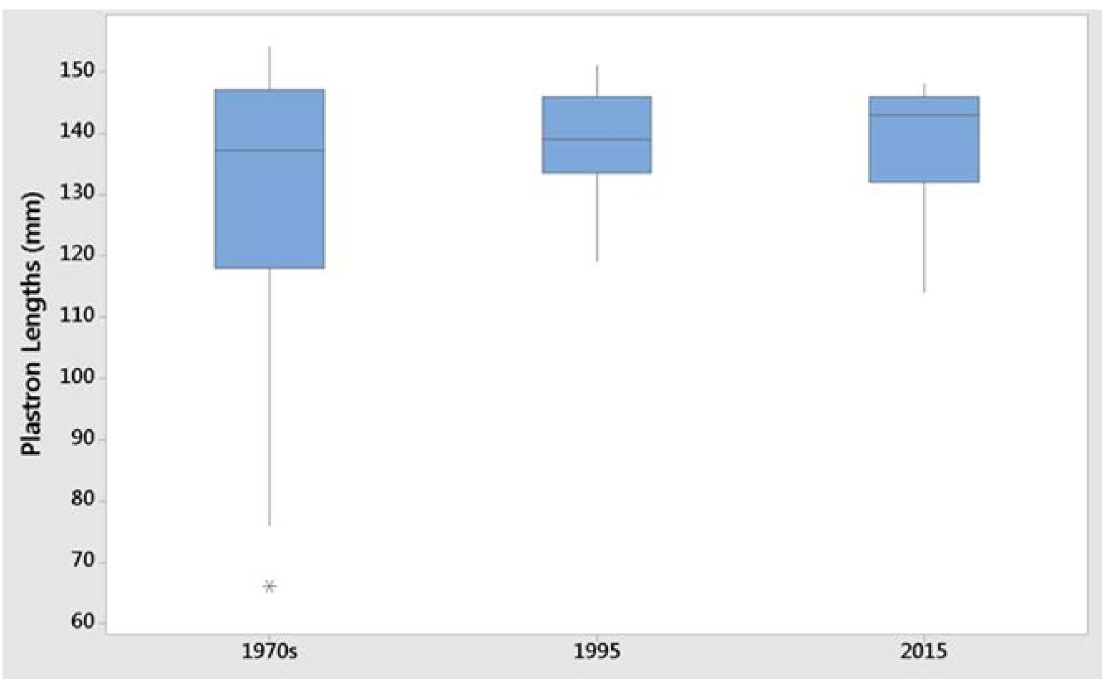

Figure 2: Boxplot of Female Plastron Lengths in the 1970s, 1995, and 2015.

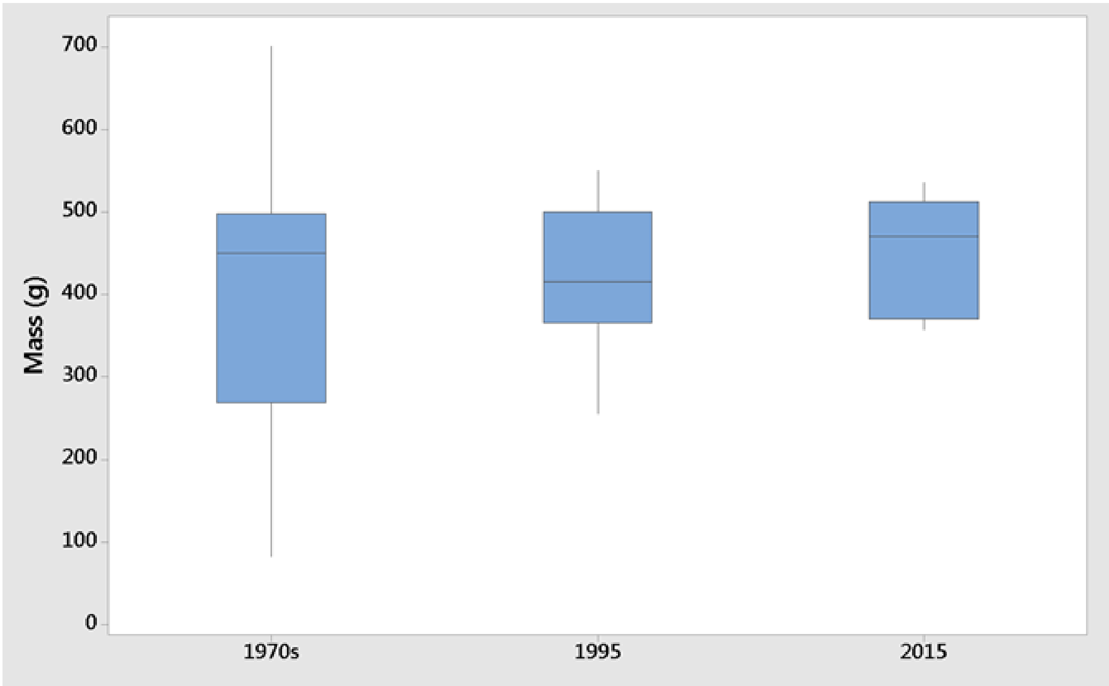

Figure 3: Boxplot of Female Masses in the 1970s, 1995, and 2015.

Home Range

Nine turtles were radio-tagged, seven adult females and two juveniles, and each was located at least six times during the study, though they were rarely observed visually. The total estimated home range areas were from 0.10 ha (Turtle 5) to 45.44 ha (Turtle 7), and the mean area was 14.57 ha (Table 4). The total home range estimates for females were from 2.60 (Turtle 3) to 45.44 (Turtle 7) and the mean home range is 18.68 ha (Table 4). The estimated home ranges for females excluding nesting forays has also been calculated. They range from 1.76 (Turtle 3) to 22.82 (Turtle 11), with a mean area of 10.78 ha (Table 4). There were seven nesting females and these are the ones to which the following statistics have been applied. The greatest distance from initial capture to first telemetry location was 773 m, the shortest was 40 m, and the mean was 309.8 m. Locations of all tracked turtles and their MCP home ranges have been mapped (Figs. 4-5)

Radio Channel	Sex	Area (ha)	Area (ha) Without Nesting Forays	Number of Times Tracked	Distance from Nesting Habitat to First Telemetry Location (m)
2	Adult Female	20.61	8.29	7	658
3	Adult Female	2.60	1.76	9	99
4	Juvenile	0.29	*	11	*
5	Juvenile	0.10	*	6	*
7	Adult Female	45.44	*	9	*
8	Adult Female	19.67	13.49	11	773
9	Adult Female	15.66	15.5	13	56
10	Adult Female	3.16	2.82	10	233
11	Adult Female	23.65	22.82	9	40

Table 4: By channel (individual), estimates of turtle home ranges and distances from nesting habitats.

*Turtle was not caught on nesting habitat.

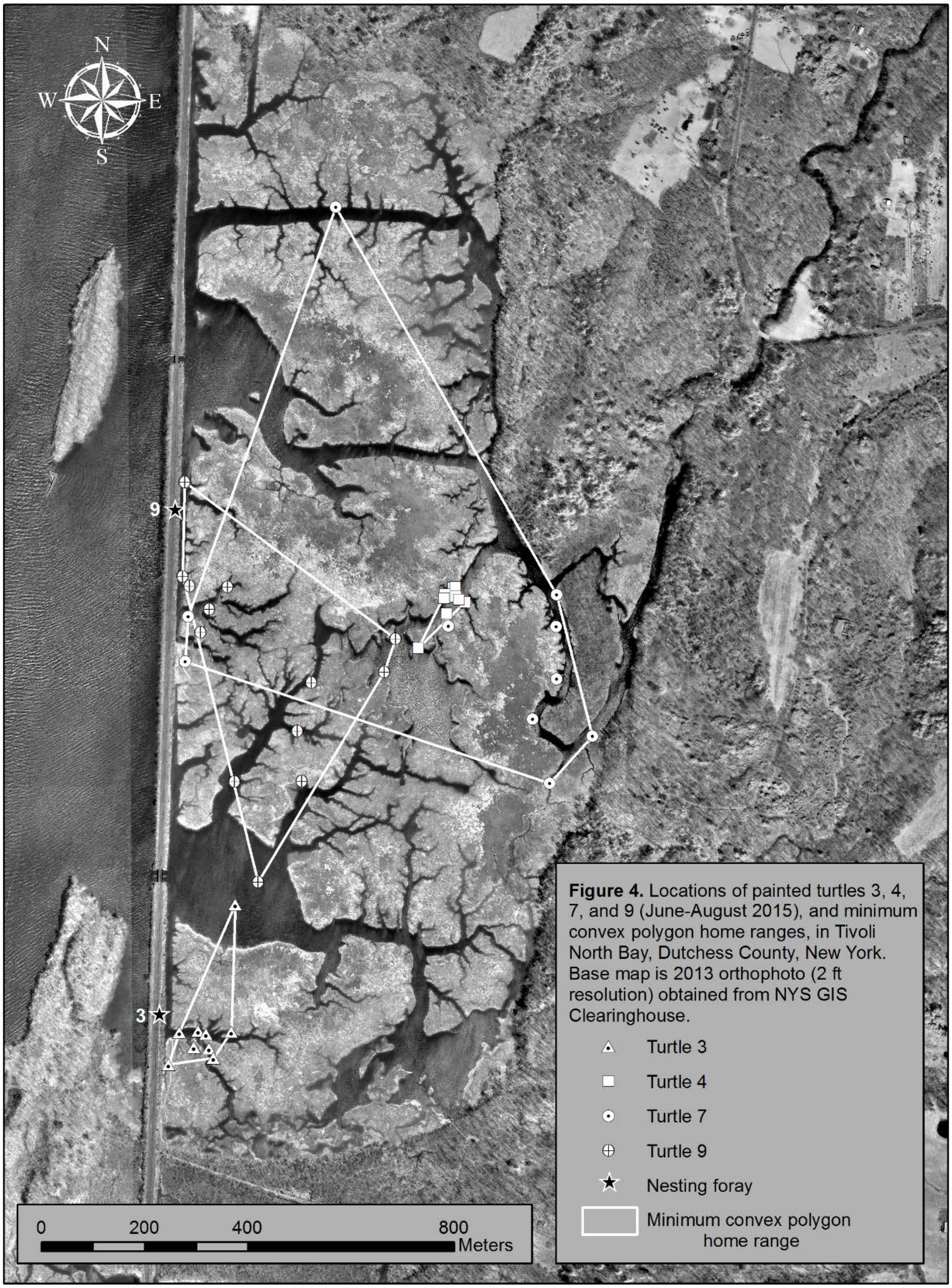

Figure 4: **The estimated home ranges of channels 2, 5, 8, 10, and 11.**

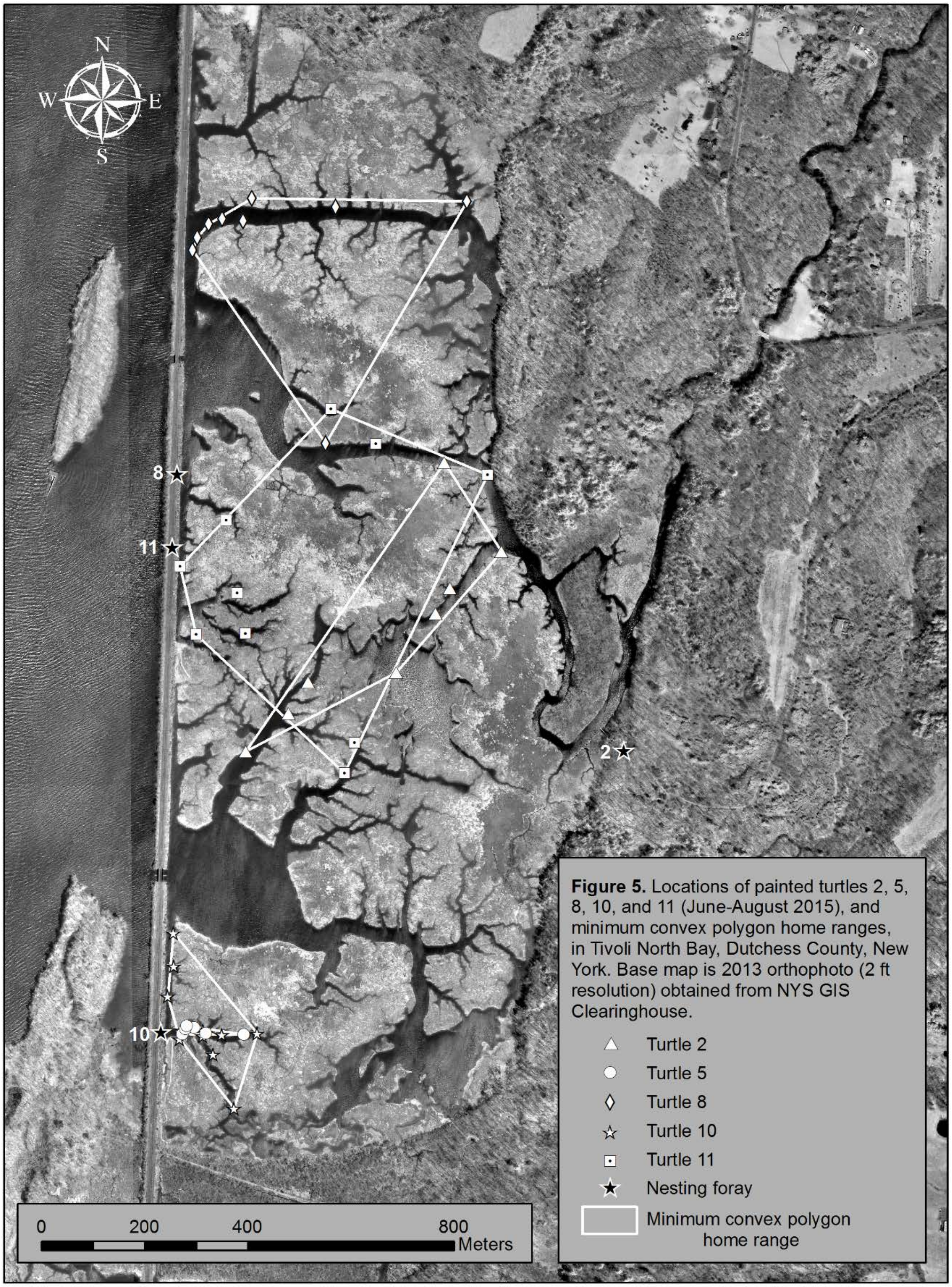

Figure 5: The estimated home ranges of channels 3, 4, 7, and 9.

DISCUSSION

Recapture rate

Of the 156 turtles captured in the 1970s and 1980s, there were only three recaptures. In the 1995 study, 21 turtles were caught with 0 repeats (i.e., within-year recaptures). In 1995 a turtle marked in 1983 was recaptured. Of the 13 individuals captured in 2015, there were no repeats (apart from radio-locations), nor any recapture from a previous year. The low recapture rates of the three studies suggest a large population, unusually short lifespans of turtles in the marsh, relatively many instances of immigration and emigration (Pulliam 1988), or insufficient sampling effort in the 1995 and 2015 studies. In contrast, the low CPUE indicates a relatively small population. The numbers of recaptures in each time period are not large enough to estimate population size.

Home Range

As of 2000, there were no home range estimates for painted turtles in the literature (Rowe 2003). Since then, several estimates for home ranges have been calculated, though none based on a population in a tidal marsh. In one study, the home ranges of painted turtles living in a very small marsh system (2.7 ha maximum) was likewise limited, with estimates at about 1.2 ha (±0.74 ha SD). Males and females were found to have similar home ranges and both adults and juveniles frequented one or more core areas. Home ranges likely depend on the distribution of resources within a habitat (Rowe 2003). Movement of painted turtles studied on the Qu'Appelle River in Saskatchewan was based on habitat quality and vegetation cover. Most adult turtles travelled 500 m or more during one season (MacCulloch and Secoy 1983). These distances are greater than some of the straight-line distances traversed by the North Bay turtles, suggesting that the movements observed in North Bay may not be unusual for painted turtles (Table 4). In total, the mean distance that males travelled each year was 5.8 km, and that females travelled was 5.4 km (MacCulloch and Secoy 1983). Qu'Appelle females moved both during and after the nesting season. The North Bay female turtles likely move throughout the nesting season as well, in order to find food and suitable nesting habitat. However, the Canadian population was studied in a river, and Tivoli North Bay is not a single linear habitat but a network of short channels.

The home ranges of the 2015 North Bay turtles were quite variable (Table 4), with turtles occasionally leaving their seemingly established ranges for brief (i.e., less than a week in duration) but relatively distant sojourns. Resources may be sparse or unevenly distributed in North Bay. Important determinants of painted turtle movements would likely include food, basking sites, predator avoidance, overwintering sites, and nesting sites. Small fishes, such as killifish (*Fundulus* spp.), are abundant in North Bay, but may only be easily caught in very shallow water at low tide (Observation, Summer 2015). The diets of North Bay painted turtles specifically are unknown. Potential perches for aerial basking, including beaver structures and logs, are moderately common in North Bay, but it is unknown whether perch distribution affects painted turtle movements. Turtles may be able to thermoregulate on exposed mud or in shallow water without aerial basking. Overwintering sites are, as yet, unknown. Nesting habitats are widely distributed along the railroad, but also occur in patches along the wooded eastern shore of the bay, and nesting migrations may involve long forays out of the home range. The expectation, based on previous research such as Rowe's (2003) Michigan study, that painted turtles move little in the marsh besides overwintering and nesting forays, has not been supported for adult turtles in North Bay. Two juveniles did remain in very small home ranges as compared to adults, which may or may not be representative of the juvenile age class (Table 4).

Two patterns in adult movement were noted. The first was an uneven home range resulting from unpredictable or seemingly random turtle movements. Turtle 2 did not have a definitive range, rather travelling continuously down a single channel as time went on. Turtle 7 moved throughout the season the most, travelling almost a thousand meters from where she was originally tracked. Her core home range is therefore much larger and more erratic than any of the others (Figs. 4-5).

The second pattern involved a smaller home range, in which turtles moved in the same areas throughout the season. Turtle 3 had a relatively restricted core area, staying in the southern end of the bay for the entire tracking season except for an excursion north to the nearest large pool in July (see Figure 4). Turtle 8 also stayed in a core area of one channel, with only one short trip to another channel. Likewise, turtle 9 was tracked over one of the most circular and consistent ranges. Turtle 10 did not shift her core area throughout the study, and had the smallest range of any adult. Turtle 11's range was larger than turtle 10's, but also relatively predictable (Figs. 4-5).

The home ranges of the juvenile turtles (turtles 4 and 5) were far smaller and their movements were more restricted, compared to the adults. Turtle 4 moved farther than she would for the rest of season immediately after she was captured, perhaps as a response to capture and handling, and spent the rest of the summer in a very limited area. Turtle 5 had the smallest range of any of the tracked turtles. The ranges of the two juveniles tracked were both in areas with near constant relatively shallow water despite the tidal fluctuations of the bay. These findings concur with MacCulloch and Secoy (1983), who documented juvenile painted turtles moving less than adults. Gervais et al. (2009) also found that painted turtles younger than four years occupied shallower water, which warms faster and allows juveniles to thermoregulate without exposing themselves to predation. Predation risk and thermoregulation therefore may have contributed to the locations and sizes of the North Bay juveniles' home ranges.

Turtle 11 was captured early in the study and erroneously released on the railroad 1,160 m south of her capture site. Nevertheless, when she was next tracked six days after release, she was found less than 200 m from her capture site. Some painted turtles can return to their capture site from kilometers away in a matter of days (Zweifel 1989). A homing study found that painted turtles repeatedly returned to capture sites within a few days if released 100 m or less away (Williams 1952). According to Williams, turtles in familiar environments might even return to their capture sites in "as little as two hours." However, turtles released 620 m or more from their capture site could take anywhere from five days up to nearly three years to return. Zweifel (1989) suggested that these returns from over 620 m, which took so much longer than the rapid movements found in Williams's study, were merely due to random wanderings, and that the turtles found their way back to their capture site by chance.

Given that turtle 11 in the 2015 Tivoli North Bay study was released more than 620 meters from her capture site and seemed to return to her home range in less than a week, it would be reasonable to assume that she was familiar with the area in which she was released. The release site was 800 meters from the next nearest tracked point in the turtle's range. This turtle therefore may move seasonally or yearly to different parts of the bay and may have a much larger long-term range than estimated here. Alternatively, she may move frequently to the area where she was released but simply was never tracked there during the study.

The fact that this turtle was able to return to her capture site may be an isolated incident, but it puts trips such as the one taken by turtle 7, which increased her home range estimate from 3.96 ha to 45.44 ha, in a new light. Travelling over 500 m from the next closest tracked point dramatically increased her home range estimate. Instead of infrequent, relatively brief, necessary trips for resources outside of the turtle's core range, these might be indicative of a much larger long-tern range than was estimated from the telemetry data. It might also be that, despite the seemingly small range of turtle 10, these individuals do not have restricted ranges but are instead familiar with large areas of the bay, and move to different locations within that habitat based on their weekly, seasonal, or annual needs (MacCulloch and Secoy 1983). With more radio-locations, the observed home ranges of all turtles could have been larger than estimated. Painted turtles are long-lived enough to familiarize themselves with rather large areas (Zweifel 1989). This is especially true when turtles are not restricted by the boundaries of a small system, such as the one studied by Rowe (2003). Studies in North Bay and other tidal marshes over multiple years and different seasons is recommended to better understand the homing abilities, long-term movements, and overwintering habitats of painted turtles in tidal marshes. The tidal nature of the bay may have unanticipated effects on turtle movement (e.g., the tides could be confusing turtles), but if turtle 11's strong homing ability is representative, this is unlikely.

Catch Per Unit Effort

CPUE comparisons are problematic because most of the 2015 hand-captures occurred on the nesting habitat and most of the 1995 hand-captures occurred in the marsh. CPUE for the marsh in the 1970s was 1.11 turtles/day, for 1995 was 0.50 turtles/day and for 2015 was 0.24 turtles/day. CPUE for traps was 0 turtles/day in the 1970s (recording may have been incomplete during snapping turtle studies), 0.10 turtles/day for 1995, and 0.00 turtles/day in 2015. The total time spent hunting turtles was greater in 1995 (35 days, 6.2 hrs/day) than in 2015 (25 days, 5.0 hrs/day). However, the inexperience of Polgar Fellows in 1995 and 2015 may partially account for the low CPUE for hand-captures in the bay. In sharp contrast to either study done on the Tivoli Bays turtles, a CPUE of 90 turtles/day in baited hoop nets was recorded in a small Michigan marsh (Rowe 2003). However, experience is more important in hand-captures than in trap captures, and no turtles were caught throughout summer 2015 in traps. Therefore, the low CPUE for trap-captures in the present study may be due to an unusually low population density of painted turtles in North Bay, a dislike for the fish bait used, turtle satiation with other food, or reluctance of painted turtles to enter traps that snapping turtles had entered first.

Body Condition

The scars and scratches found on the captured turtles in 2015 were minor, usually less than 2 cm x 1 cm. It is unlikely that the North Bay turtles are being injured by vehicular traffic because turtles hit by cars, other road vehicles, or mowing machinery show much more severe wounds that typically include cracks in the shell. Moreover, the nearest road to North Bay (Kidd Lane) is ca. 600 m away from the closest painted turtle radio-location, thus it is unlikely that the study population is exposed to much automotive traffic. Some painted turtles are probably hit by trains, but these individuals probably do not survive to bear scars.

Raccoons have been noted on the railroad where females nest and in the marsh itself (Observation, Summer 2015). Raccoons prey on eggs, young turtles, and adults (Erickson and Scudder 1947). Predation attempts by raccoons may leave teethmarks on the shell or missing limbs on the confamilial wood turtle (*Clemmys insculpta*) (Farrell and Graham 1991). Ospreys, northern harriers, and bald eagles, all of which prey on painted turtle young and adults (Watts et al. 2007, Ernst and Lovich 2009), were also observed on an island less than 120 m from the turtle nesting habitat on the railroad (Observation, Summer 2015).

Several turtles caught in the 1970s and 1995 had missing claws or feet, but in 2015, no captured turtles were missing any appendages (Table 2). Across the three periods, neither the proportion of missing claws nor the proportion of missing feet was statistically significant, so if the damage reliably indicates predation attempts, the data do not support different predation rates in different time periods.

Differences in CL, PL, and mass of females among the three time periods were not significant (Figs. 1-3). In 2015, 27.8% of turtles had anomalous scutes of some kind, a high percentage compared with the 1995 proportion (14.3%) or the 1970s proportion (10.2%). When only females were compared with Fisher's Exact Test on a 2 x 3 table comparing two body conditions to three time periods with 95% confidence in Minitab, the proportions of anomalous scutes were significantly different. Females captured in 2015 had significantly more abnormal scutes.

The Hudson River is contaminated with heavy metals (lead, zinc, copper, gold, and cadmium) as well as polychlorinated biphenyls (PCBs) (Huan et al. 1998). Furthermore, the creosote used to preserve railroad ties like the ones used on the Tivoli North Bay railroad is a source of polycyclic aromatic hydrocarbons (PAHs) (Moret et al. 2007). A study was conducted on turtles exposed from a young age to PAHs, polychlorinated biphenyls, and elements such as lead, mercury, copper, cadmium, and arsenic, all from a nearby landfill. Lethal deformities were more common than moderate or minor deformities. Mean annual deformity rate over four years ranged from 45% to 71%, and exposure to higher levels of PAHs was correlated with high rates of deformity (Bell et al. 2006). Although the 1995 North Bay turtles had a lower proportion of deformities than those exposed to PCBs as hatchlings (Bell et al. 2006), and the Bell study not only included anomalous scutes but other, visually obvious deformities, the comparison is not completely apt. However, the significantly higher occurrence in 2015 of anomalous scutes, which may be considered minor deformities, is striking. No turtles with obviously major deformities were captured in 2015, but such turtles may have died before capture. The female North Bay turtles may be affected by the chemicals leaching off the railroad near their nesting habitats.

In 2015, the carapaces of both of the captured males, five of the eight females, and two of the three juveniles showed algal growth visible to the naked eye. In contrast, less than 10% of the 549 painted turtles in a survey of specimens from Northwestern University showed signs of algae of the genus *Basicladia* (Edgren et al. 1953). The low occurrence of algal coverage on the Edgren et al. study was thought to be due to frequent aerial basking. The preference that painted turtles have for habitats with abundant basking sites, including the shores of channels, has been well-documented. Aggressive behaviors are associated with competition for basking sites, including openmouthed gesturing, biting, and pushing (Lovich 1988). Painted turtles have been found basking on the carapaces of snapping turtles (Legler 1956), of which there are many in North Bay.

However, turtles in North Bay were rarely observed to bask aerially, despite the fact that much of the time spent tracking encompassed two of the three most common times for turtles to bask: midday and early afternoon (Ernst and Lovich 2009). Logs and coarse woody debris (CWD) are available at a moderate density throughout the parts of the bay thought to contain relatively high densities of painted turtles. However, turtles were rarely observed basking on the banks of channels or on CWD, though they could have easily done so (Observation, Summer 2015). The absence of turtles on these basking sites may indicate that they do not need to aerially bask, but that the tidal nature of the bay allows them to collect sufficient thermal energy by staying in shallow sun-warmed water and mud at low tide. This might be safer than aerial basking, as potentially fewer predators could sense them. Lack of conspicuous aerial basking could also indicate the poor health of the population, because turtles need to bask daily for thermoregulation and removal of ectoparasites (Ernst and Lovich 2009). If North Bay painted turtles thermoregulate more in shallow water or on low tide mudflats, rather than basking aerially, they might have less opportunity to shed algal growth and may accumulate more leeches. Over half the turtles in each sex group hosted at least one leech. It is likely that North Bay turtles thermoregulate mainly in shallow sun-warmed water, giving them less opportunity to rid themselves of algae and leeches.

The plastron lengths, carapace lengths, and masses of turtles caught in this study were not significantly different from those caught twenty years ago. However, the sizes of males compared to females were significantly different, which was as expected. Low recapture rates may be due to insufficient sampling effort, large population, or high rates of immigration and emigration. Radiotelemetry data indicate variable home range size including some unexpectedly large ranges. Painted turtles may be gaining enough thermal energy by remaining in shallow water and mud flats, as very little aerial basking was observed. More studies are needed in North Bay and in other tidal marches to more thoroughly describe the movement patterns and ecology of painted turtles.

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