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# Size records and demographics of an Eastern Painted Turtle (*Chrysemys picta picta*) urban population near the northern limit of the species' range in eastern Canada

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## Abstract

Understanding variation in demographics and life history across species ranges and differing landcover types is valuable for conservation planning. We examined the population demographics of a small urban population of Eastern Painted Turtle (*Chrysemys picta picta*) in New Brunswick, Canada, near the northern limit of the species' range. We captured turtles using hoop traps and by hand during four sampling periods. We estimated that our population included 17 females, nine males, and 29 juveniles in late summer 2015 using Jolly-Seber population size estimates. We captured several very large females at our study site; 5/17 females (29%) were larger than previous size records for the subspecies. Growth rates for juveniles were greater than most populations of Eastern Painted Turtles reported elsewhere. Growth rates at our site were significantly greater for smaller (younger) turtles and for females compared to males. Overwinter survivorship estimates were 100% from late summer 2014 to spring 2015. Active season (2015) survivorship was 100% for females, 89% for males, and 93% for juveniles. We speculate that the large body sizes found at our study site were achieved through high survivorship and larger growth rates compared to other areas reported previously. Our data supports previous findings that body size of Painted Turtles increases with latitude, and additionally, growth may have been enhanced by increased nutrient levels common in human-modified landscapes.

Key words: Age structure; growth; Jolly-Seber; mark-recapture; maximum size; New Brunswick; sex ratio; size structure; survivorship; urban

## Résumé

La compréhension des variations démographiques et biologiques entre les types d'habitats et géographiquement est précieuse pour la planification de la conservation. Nous avons examiné les données démographiques d'une petite population urbaine de Tortues Peintes de l'Est (*Chrysemys picta picta*) au Nouveau-Brunswick, Canada, près de la limite nord de l'aire de répartition de l'espèce. Nous avons capturé des tortues à l'aide des cerceau piège et à la main pendant quatre périodes d'échantillonnage. Nous avons estimé que notre population comprenait 17 femelles, neuf mâles et 29 juvéniles à la fin de l'été 2015 en utilisant les estimations de la taille de la population de Jolly-Seber. Nous avons capturé plusieurs très grosses femelles sur notre site d'étude; cinq des 17 femelles (29%) étaient plus grandes que les records de taille précédents pour la sous-espèce. Les taux de croissance des juvéniles étaient supérieurs à ceux de la plupart des populations de Tortues Peintes de l'Est signalées ailleurs. Les taux de croissance sur notre site étaient significativement plus élevés pour les tortues plus petites (plus jeunes) et pour les femelles par rapport aux mâles. Les estimations de la survie hivernale étaient de 100% de la fin de l'été 2014 au printemps 2015 (hiver). La survie pendant la saison active (2015) était de 100% pour les femelles, de 89% pour les mâles et de 93% pour les juvéniles. Nous supposons que les grandes tailles corporelles trouvées sur notre site d'étude ont été obtenues grâce à une survie élevée et à des taux de croissance plus importants par rapport à d'autres zones signalées précédemment. Nos données corroborent les conclusions précédentes selon lesquelles la taille corporelle des tortues peintes augmente avec la latitude et, en outre, la croissance peut avoir été améliorée par l'augmentation des niveaux de nutriments courants dans les paysages modifiés par l'homme.

Mots clés : Croissance; Jolly-Seber; marquage-recapture; Nouveau-Brunswick; rapports de masculinité; structure par âge; structure de taille; survie; taille maximum; urbaine

## Introduction

Turtles are the most threatened taxa among the major groups of vertebrates (Lovich *et al.* 2018). Historically, turtles had much larger population sizes, thus their declines are suspected to have significant impacts on ecosystem processes (Lovich *et al.* 2018). All turtle species native to Canada are now considered to be at-risk in at least parts of their range (COSEWIC 2022). Even the widely distributed and abundant Painted Turtle (*Chrysemys picta*) has experienced declines significant enough to warrant the status of Special Concern in Eastern Canada and Threatened for the Pacific Coast population (COSEWIC 2016, 2022). Turtles are impacted by a multitude of threats (including, but not limited to: habitat loss, road mortality, subsidized predators, invasive species, climate change, fisheries by-catch, pollution, disease, and collection) and their ability to withstand these impacts are limited due to their life history characteristics of late age of maturity and high adult survivorship coupled with low juvenile recruitment (Burger and Garber 1995; COSEWIC 2018). Understanding variation in demographics and life history characteristics among landcover types and geographically will be valuable for recovery planning.

Painted Turtle is one of the most abundant and widely distributed turtle species, making it a valuable subject to compare geographical variation of intraspecific ecological parameters (Zweifel 1989). Three subspecies exist (Crother 2017): Western Painted Turtle (*Chrysemys picta bellii*), Midland Painted Turtle (*Chrysemys picta marginata*), and Eastern Painted Turtle (*Chrysemys picta picta*). The subspecies differ in colour, morphology, and size (Conant and Collins 1991; Ernst *et al.* 1994). Western Painted Turtles tend to grow larger than the other subspecies (Ernst *et al.* 1994). Larger body size may have reproductive advantages because larger females tend to produce larger clutches of eggs (Tinkle *et al.* 1981; Iverson and Smith 1993; Rowe 1994). Size also varies geographically within the subspecies and among differing landcover compositions. Body size is positively correlated with latitude and elevation (Iverson and Smith 1993) and relatively larger body sizes have been observed for Painted Turtles in nutrient rich habitats, such as wastewater lagoons and golf course ponds (Ernst and McDonald 1989; Lindeman 1996; Failey *et al.* 2007).

We examined population size, structure, survivorship, age/size distribution, sex ratios, and growth for a small, urban population of Eastern Painted Turtle in New Brunswick. Our results are particularly valuable because they are the first demographic analysis for a Canadian population of Eastern Painted Turtle. Also of interest, our study population is a small population located in an urban park. Small populations are of special interest with respect to minimum population size and long-term population viability (Soule 1987). Urbanization is rapidly altering habitats worldwide; thus, information from urban populations will be particularly valuable for conservation efforts.

## Methods

*Study area*

Our study occurred in a network of lakes in Rockwood Park (45.2941°N, 66.0591°W) located in Saint John, New Brunswick, Canada. Rockwood Park is one of the oldest and largest city parks in Canada, established in 1896, and covers ~695 ha within park boundaries. There are 10 large lakes (1.4–10.3 ha) and several ponds (up to 0.8 ha) in Rockwood Park. Each of the lakes is connected by water bodies outside of the park; Crescent Lake drains to Alder Brook, while the other nine lakes drain to streams that feed into Marsh Creek. Lily Lake and Fisher Lakes are located within the park's designated recreation zone and are heavily used by the public for events and low impact recreation (e.g., hiking, cycling, swimming, angling, non-motorized boating, horseback riding, and dog exercise). Crescent Lake is located adjacent to the Rockwood Park golf course and was used for an aquatic driving range from 1973 to 2013; the aquatic driving range was closed from 2014 to 2017 but reopened in 2018. The other seven lakes are located within the park's designated wilderness area. The wilderness area has comparatively less human impact; however, it is used for low impact recreation.

*Turtle community*

We surveyed for turtles at all 10 lakes, plus four smaller waterbodies in Rockwood Park (39.4 ha open water surface area) and at four waterbodies outside of the park in Saint John (37.9 ha open water surface area) from 2014 to 2016. Three species of turtles were found in Rockwood Park: Eastern Painted Turtle, Snapping Turtle (*Chelydra serpentina*), and the non-native Red-eared Slider (*Trachemys scripta elegans*). An Eastern Painted Turtle population resides at Crescent Lake in Rockwood Park with some use of a small pond in the golf course during the summer. Snapping Turtles are widely distributed in Rockwood Park; members of the public have submitted nine confirmed observations (photo evidence or expert identification) and 14 unconfirmed observations (observations reported without photo evidence) from a wide range of locations within the park or along its perimeter as well as seven locations (two confirmed, five unconfirmed) outside of the park in the city of Saint John. However, our trapping efforts from 18 sites only produced three individuals with 2669 trap days, which suggests that Snapping Turtles are at very low abundance (C.L.B. and S.A.S. unpubl. data). Red-eared Sliders are released pet turtles that occurred at Lily Lake and the Fisher Lakes area (Browne and Sullivan 2023). We caught and removed six individuals from Rockwood Park from 2014 to 2016 and implemented a public education program to discourage the release of pets in the park. Only one additional Red-eared Slider has been sighted (and removed in 2022) since the six individuals were removed during 2014–2016.

*Field methods*

We used six baited hoop traps to catch turtles at Crescent Lake (7.4 ha open water surface area). Hoop traps were 84 cm long, had three oval hoops 45–48 cm in diameter, 2.5 cm mesh, and were baited with chopped native fish donated by local anglers (Browne and Sullivan 2023). We deployed traps during four sampling periods: (1) 24 August–12 September 2014 (sample one = Late Summer 2014), (2) 12 May–17 June 2015 (sample two = Spring 2015), (3) 24 August–27 September 2015 (sample three = Late Summer 2015), and (4) 17 May–15 June 2016 (sample four = Spring 2016) and checked traps daily. We also captured individuals by hand or dip-net when possible during the sampling periods. Painted Turtles from the Crescent Lake population were also captured at the golf course pond and Harrigan Lake during exploratory sampling in August 2016.

We sexed, measured, marked, and photographed each turtle captured. Individuals were identified as male if they exhibited the presence of secondary sex characteristics (elongate foreclaws, enlarged tail base, and more posterior positioning of the vent; Cagle 1954; Christiansen and Moll 1973). We designated individuals not exhibiting male secondary sex characteristics as juveniles if straight midline carapace length (MCL; as per Method D in Iverson and Lewis 2018) was <13 cm and as females if MCL was ≥13 cm based on a natural break observed in the size structure of our population (Figure 1). We recorded MCL, straight maximum carapace length (Method B, Iverson and Lewis 2018), straight maximum carapace width, and straight midline plastron length (Method H, Iverson and Lewis 2018) with Vernier calipers (Grand Rapids Industrial Products, Wayland, Michigan, USA) to the nearest mm. We weighed turtles to the nearest 5 g using a spring scale (Pesola, Schindellegi, Switzerland) from 3 June 2016 on. We marked turtles using Cagle's (1939) method to provide a unique notch code for each turtle marked. We recorded any abnormalities present and the number of growth lines present if clearly visible. Females were recorded as gravid if eggs could be felt by palpating the cavity in front of the hind legs.

*Data analysis*

We used the Jolly-Seber method (Jolly 1965; Krebs 1999) in the program Ecological Methodology Version 5.2 (Exeter Software 1999) to calculate estimates

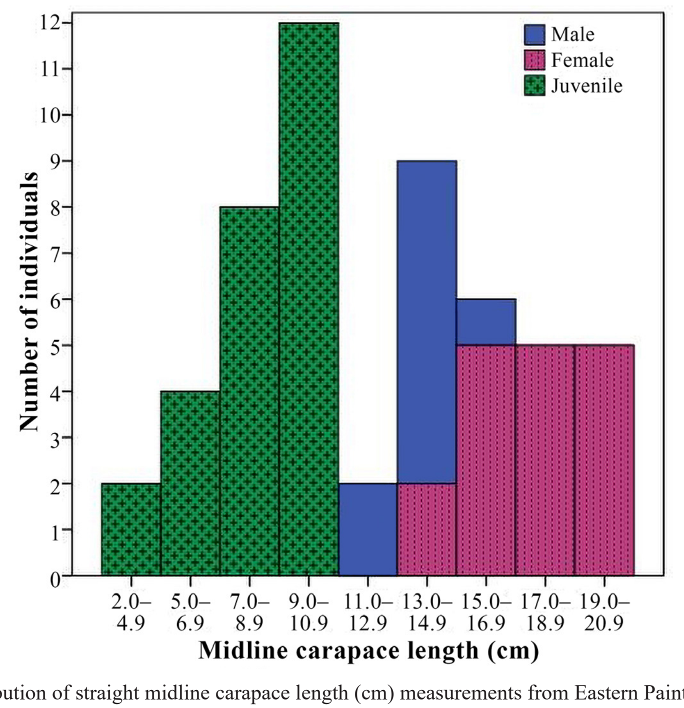


**Figure 1.** Size distribution of straight midline carapace length (cm) measurements from Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick in 2014–2016 ($n$ = 53).

for population size and survival probability. The assumptions of the Jolly-Seber method are: (1) every individual has the same probability of being caught in the *t*-th sample, regardless whether it is marked or unmarked; (2) every marked individual has the same probability of surviving from the *t*-th to the ($t + 1$)-th sample; (3) individuals do not lose their marks, and marks are not overlooked at capture; and (4) sampling time is negligible in relation to intervals between samples (Jolly 1965; Krebs 1999). We believe that our sampling methods met the assumptions, except for assumption #1. Catchability differed among males, females, and juveniles (Table 1), thus we calculated Jolly-Seber estimates for males, females, and juveniles separately to resolve this violation. Previous studies have also found that hoop traps overrepresent males and underrepresent juveniles (Ream and Ream 1966; Vogt 1979), while captures by hand or dipnet tend to produce less biased results (Ream and Ream 1966; Bider and Hoek 1971). Both of our capture methods were biased towards capturing adults over juveniles and males over females (Table 1), with the bias being more significant for hoop traps ($\chi^2_2 = 42.71$, $P < 0.001$) than dipnet and hand captures ($\chi^2_2 = 10.89$, $P < 0.005$).

A minimum of three samples are required to obtain population estimates. We used data collected from four sample periods that allowed us to calculate survivorship estimates for both the active season and overwintering period. Two males that were missing from Crescent Lake during the spring 2016 sample, but found nearby in late summer 2016 were added to the spring 2016 sample to prevent underestimating survivorship and population size. Input data are provided in Table S1. With these four sample periods, we obtained estimates of population size at sample two (Spring 2015) and sample three (Late Summer 2015), the probability of survival from sample one to sample two (overwintering period 2014–2015) and from sample two to sample three (active season 2015), and the proportion of the population marked in samples two, three, and four (Spring 2016).

We examined the sex and age ratio of the population by comparing the number of males to females, and adults to juveniles, respectively. Because the capture ratios are biased, we used the Jolly-Seber population size estimates to calculate these ratios. We used the most recent MCL measurement taken from each individual to examine size structure of the population.

We calculated growth overwinter and during the summer by measuring the difference in MCL between trapping sessions. We calculated annual growth rates by measuring the difference in MCL between the Late Summer 2014 to Late Summer 2015 sessions or Spring 2015 to Spring 2016 sessions. We used a generalized linear model (GLM) with normal distribution and identity link function to determine whether the independent variables sex, initial MCL size, or sampling period influenced the amount of growth for three dependent variables: annual growth, overwinter growth, or summer growth. We also used GLM to examine the relationship with sampling session (Spring 2016 or Late Summer 2016), age/sex, and MCL on weight. We considered $\alpha < 0.05$ to indicate statistical significance. We used IBM SPSS Statistics Version 24 for statistical tests (IBM Corp. 2016).

## Results

*Captures*

We captured a total of 53 individual Painted Turtles in Rockwood Park by the end of our fourth sampling period: 10 males, 17 females, and 26 juveniles. Jolly-Seber estimates indicated that we marked all of the adults in this population and ~86% of the juveniles (Table S2). In the third and fourth sampling periods, all the adult turtles caught were recaptures; the only new captures were six juveniles in fall 2015 and three juveniles in spring 2016.

We caught nearly every marked individual in Spring 2016 (final) sample: seven males, 17 females, and 21 juveniles. Two of the missing males were confirmed to be alive later in the summer of 2016, found at the golf course pond and Harrigan Lake located 230 m and 580 m straight-line distance from Crescent Lake, respectively. The third missing male was caught in sample one and two, but not three or four; the fate of this individual is unknown. Five marked

**TABLE 1.** Bias among male, female, and juvenile Eastern Painted Turtle (*Chrysemys picta picta*) captured in Rockwood Park, New Brunswick from 2014 to 2016 using hoop-traps and other methods was examined by comparing the percent of the population (calculated using Jolly-Seber population size estimates; see Table 2) to the percentage of turtles caught in traps ($n$ = 192) or by dipnet/hand ($n$ = 154).

| | % of Population (*N*) | Trapped | | | Dipnet and hand captures | | |
|---|---|---|---|---|---|---|---|
| | | *n* | % | %/%*N* | *n* | % | %/%*N* |
| Male | 16 | 59 | 31 | 1.94 | 38 | 25 | 1.56 |
| Female | 31 | 93 | 48 | 1.55 | 58 | 38 | 1.23 |
| Juvenile | 53 | 40 | 21 | 0.40 | 58 | 38 | 0.72 |

juveniles were not captured in 2016. We know one individual died and assume a second individual to have also died; they were observed with throat/mouth infections in late summer 2015, and one individual was sent to the Atlantic Wildlife Institute, where it died soon after arriving (see Browne *et al.* 2020 for more details). The individual that was not removed from the site had more severe symptoms, thus we assume that it is also died. The remaining three juveniles were last captured in late summer 2015 ($n = 1$) and spring 2015 ($n = 2$).

*Population size estimates*

The Jolly-Seber population size estimate for the Painted Turtle population calculated for sample two (Spring 2015) was 50 turtles (43–72 individuals, 95% CI), which included 10 males, 17 females, and 23 juveniles (Table 2). The population size estimate for sample three (Late Summer 2015) was 55 turtles (48–74 individuals, 95% CI), which included nine males, 17 females, and 29 juveniles. Crescent Lake is 7.4 ha, so the known density is 3.5 adult turtles/ha. Using the total population size estimate of 48–74 individuals, the density of this population is estimated to be 6.5–10 turtles/ha.

*Survivorship*

The Jolly-Seber survival probability estimates from Late Summer 2014 to Spring 2015 were all 1.000, which indicates that virtually all individuals survived the 2014–2015 winter (Table 3). Active season survival estimates (Spring 2015 to Late Summer 2015) were 1.000 for females, 0.890 for males, and 0.931 for juveniles (Table 3).

*Population structure*

The sex ratio of this population is female biased (M:F 1:1.9) and although more adult turtles were captured than juveniles, Jolly-Seber estimates indicate that the adult to juvenile ratio is 1:1.1. The size distribution of MCL ranged from 2.5 to 20.7 cm (Figure 1). Average MCL was 17.5 ± (SE) 0.5 cm for females (range 14.3–20.7 cm, $n = 17$), 13.7 ± 0.3 cm for males (range 12.3–15.3 cm, $n = 10$), and 8.1 ± 0.4 cm for juveniles (range 2.5–10.3 cm, $n = 26$).

*Growth*

MCL growth occurred primarily during the summer period (Table S3). MCL growth did not differ significantly between years; sex/age and initial MCL were significant factors for MCL growth (Table S4). MCL growth was significantly greater for smaller turtles (Table S4). Juveniles experienced the greatest amount of MCL growth, followed by males then females (Table S3). However, annual MCL growth was greater for females compared to males of similar size (Figure 2, Table S4). Mass was significantly related with turtle MCL and sex/age, but not sampling session (Table S5, Figure S1). Juveniles had a lower mass to MCL ratio than adults ($P < 0.001$), the difference was not significant between females and males ($P = 0.088$). Juveniles began to reach adult size at ~3.5–4 years old (Table 4, Figure S2). The smallest male with secondary sexual characteristics was 11.4 cm in MCL. We only detected eggs in five individuals because our sampling did not directly overlap with the nesting period, but of these, the smallest gravid female observed was 15.9 cm.

**TABLE 2.** Jolly-Seber population size estimates for Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick for sampling period two (Spring 2015) and three (Fall 2015).

| Group | Sample 2 (Spring 2015) | | | Sample 3 (Late Summer 2015) | | |
|---|---|---|---|---|---|---|
| | Estimate | SE | 95% CI | Estimate | SE | 95% CI |
| Males | 10.1 | 0.4 | 9.5–11.8 | 9.0 | 3.0 | 9.0–9.0 |
| Females | 17.0 | 0.5 | 16.4–18.5 | 17.0 | 4.1 | 17.0–17.0 |
| Juveniles | 22.6 | 5.3 | 16.6–41.6 | 28.8 | 8.2 | 21.5–48.2 |
| Sum | 49.7 | | 42.5–71.9 | 54.8 | | 47.5–74.2 |

**TABLE 3.** Jolly-Seber probability of survival for Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick from sample one (Late Summer 2014) to sample two (Spring 2015) and sample two (Spring 2015) to sample three (Late Summer 2015).

| Group | Late Summer 2014 to Spring 2015 | | | Spring 2015 to Late Summer 2015 | | |
|---|---|---|---|---|---|---|
| | Estimate | SE | 95% CI | Estimate | SE | 95% CI |
| Males | 1.000 | 0.023 | 0.639–1.000 | 0.890 | 0.104 | 0.664–1.000 |
| Females | 1.000 | 0.000 | 0.686–1.000 | 1.000 | 0.000 | 0.951–1.000 |
| Juveniles | 1.000 | 0.073 | 0.672–1.000 | 0.931 | 0.133 | 0.694–1.000 |
| Mean | 1.000 | 0.032 | 0.666–1.000 | 0.940 | 0.079 | 0.770–1.000 |

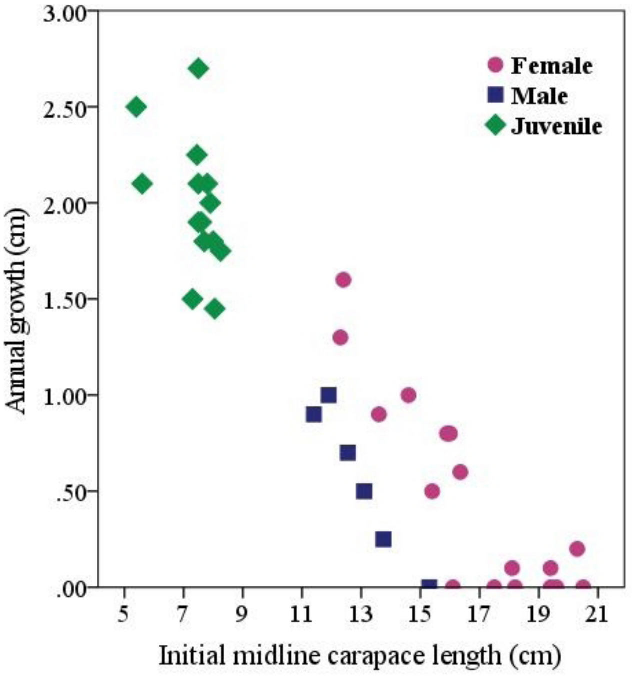


**FIGURE 2.** Annual straight midline carapace length growth was greater for smaller/younger Eastern Painted Turtle (*Chrysemys picta picta*) and for females compared to males of similar size in Rockwood Park, New Brunswick.

**TABLE 4.** Straight midline carapace length (Method D in Iverson and Lewis 2018) and straight midline plastron length (Method H in Iverson and Lewis 2018) of each age class of juvenile Eastern Painted Turtle (*Chrysemys picta picta*) captured in Rockwood Park, New Brunswick, from 2014 to 2016. Age was estimated by counting growth rings. Recaptures were included but each individual was not included more than once per sampling session. We assigned hatchlings observed in the Spring with no growth accumulated to age class 0 years for a starting point. Estimated ages of 0, 1, 2, 3, and 4 years are measurements taken from the Spring sampling sessions; estimated ages of 0.5, 1.5, 2.5, and 3.5 years are measurements taken from the Late Summer sampling sessions.

| Age | *n* | Carapace (cm) | | | Plastron (cm) | | |
|---|---|---|---|---|---|---|---|
| | | Mean | SE | Range | Mean | SE | Range |
| 0.0 | 1 | 2.5 | | 2.5–2.5 | 2.4 | | 2.4–2.4 |
| 0.5 | 2 | 6.5 | 1.03 | 5.5–7.5 | 6.0 | 1.05 | 4.9–7.0 |
| 1.0 | 6 | 5.3 | 0.25 | 4.4–6.1 | 4.7 | 0.17 | 4.1–5.3 |
| 1.5 | 12 | 7.5 | 0.15 | 6.4–8.1 | 6.9 | 0.13 | 6.1–7.5 |
| 2.0 | 15 | 7.7 | 0.10 | 6.8–8.3 | 7.0 | 0.09 | 6.4–7.7 |
| 2.5 | 8 | 9.8 | 0.36 | 9.1–12.3 | 9.3 | 0.38 | 8.5–11.9 |
| 3.0 | 13 | 9.7 | 0.13 | 8.8–10.3 | 9.1 | 0.12 | 8.3–9.6 |
| 3.5 | 1 | 12.2 | | 12.2–12.2 | 11.7 | | 11.7–11.7 |
| 4.0 | 3 | 13.4 | 0.32 | 12.9–14 | 12.9 | 0.36 | 12.2–13.4 |

*Movement and dispersal*

We caught 12 individuals at the golf course pond, located 230 m straight-line distance from Crescent Lake, from 4 to 10 August 2016, and one individual at Harrigan Lake, located 580 m from Crescent Lake, on 3 August 2016. Each of these turtles were originally caught and marked at Crescent Lake. The Painted Turtles appear to use the golf course pond for summer habitat but return to Crescent Lake for overwintering. The Painted Turtle that moved from Crescent Lake to Harrigan Lake was not captured at Crescent Lake in subsequent samples and was one of the few individuals not accounted for in the Spring 2016 sampling period, thus may be a dispersal event.

## Discussion

The Rockwood Park Painted Turtle population is small with only 17 adult females and nine adult males. This small, urban population may seem inconsequential, but our study revealed unique features that offer special conservation significance. Five females, representing 29% of the adult female population, were larger than the maximum size previously recorded for this subspecies: 18.98 cm, an individual from Gagetown, New Brunswick (Ultsch *et al.* 2000). Our largest individual was 20.7 cm. The mean size of adult females at our site was larger than that from other areas for Eastern Painted Turtle (Conant and Collins 1991; Rhodin and Mittelhauser 1994; Ultsch *et al.* 2000). Thus, our data support previous findings that body size of Painted Turtles increases with increasing latitude (Iverson and Smith 1993; Rhodin and Mittelhauser 1994; Ashton and Feldman 2003). The several new size records from Rockwood Park could be because the subspecies is poorly sampled near its northern range limit where individuals are expected to be larger. Sample sizes for New Brunswick studies (14 adult females in Ultsch *et al.* 2000; 17 adult females in our study) have been small in comparison to other areas (e.g., 122 adult females in Maine and 247 in Massachusetts; Rhodin and Mittelhauser 1994). This northern area of the subspecies' distribution has much potential for discovering new information about geographical variation within this subspecies.

Iverson and Smith (1993) list several explanations for why body size and latitude are correlated for Painted Turtles, including (1) larger body size is advantageous in cooler climates because rates of heat loss are theoretically lower (Lindsey 1966); (2) large body size facilitates survival through the winter (Murphy 1985); (3) small body size is an adaptive response to increased competition with other large emydid turtles in the southern part of its range (Moll 1973); (4) larger females dig deeper nests (Morjan 2003), which might decrease overwinter mortality of hatchlings from freezing temperatures (St. Clair and Gregory 1990); and (5) larger body size allows greater single clutch reproductive output (Iverson and Smith 1993).

Painted Turtles often have indeterminant growth (Congdon *et al.* 2013), thus large body sizes could be achieved through faster growth rates, delayed age of maturity, and/or higher survivorship rates. Juvenile turtles at our study site during our study period grew more rapidly than those at a long-term study site for Eastern Painted Turtles in Long Island, New York (Zweifel 1989). Age-size comparisons shifted across studies: one year old turtles at our site were smaller on average than at Zweifel's (1989) site (mean MPL = 4.7 versus 5.04 cm), were similar sizes by two years (7.0 versus 7.02 cm), and larger by three years (9.1 versus 8.32 cm) and four years (12.9 versus 9.12 cm). Juveniles from our site and Zweifel's (1989) also grew more rapidly than those from a site in Michigan (Frazer *et al.* 1993). Adult turtles at our site also grew during our study period, but growth rates were greater for smaller (presumably younger) turtles and for females compared to males. Having 5/17 females larger than the previous size record seems extraordinary, so we suspect that additional factors could be playing a role at our site. Rapid growth rates could result from enhanced thermal environments (Gibbons *et al.* 1981; Thornhill 1982; Frazer *et al.* 1993), nutrient rich environments resulting in availability of preferred food items (Lindeman 1996; Failey *et al.* 2007), and delayed maturity to direct energy to growth rather than reproduction (Iverson and Smith 1993). Increased nutrient levels in human-modified landscapes, such as wastewater lagoons and golf course ponds, may provide turtles with more abundant food sources (Budischak *et al.* 2006; Failey *et al.* 2007; Roe *et al.* 2011). This could potentially explain the rapid growth rates at our site because our study lake was located adjacent to a golf course and at least 12 adults from our population moved seasonally to use a small pond located within the golf course during the summer. Water chemistry samples collected at our study lake on 19 August 2008 indicated that orthophosphate levels were 0.03409 mg/L (Table S6), which is considered to be meso-eutrophic (CCME 2004). Elevated nutrient levels and food opportunities could explain why turtles made seasonal movements to the golf course ponds. Alternatively, it could also be related to thermoregulation opportunities. The golf course ponds likely reach higher temperatures in the summer because they are small, shallow, and in full sun, which would increase metabolic rates and the ability to digest food more rapidly for the turtles.

The population at Rockwood Park appears to have high survivorship. Survivorship was estimated to be 1.000 overwinter for 2014–2015, and summer survivorship in 2015 was estimated to be 1.000 for females, 0.890 for males, and 0.931 for juveniles (Table 3). Additionally, we assume that the presence of several very large females in our population indicates that survivorship rates have been high in previous years as well. Our sample most likely captured the entire adult population, but the population was not large enough to effectively compare survivorship to other populations, because the loss of just one adult male made the survivorship rate 0.890 compared to 1.000 if this male had been recaptured. However, our survivorship rates are comparable to other populations. Annual survivorship rates in Long Island averaged 0.810 for males (range 0.330–1.000) and 0.923 for females (range 0.714–1.000) from 1963 to 1979 (Zweifel 1989). In Algonquin Park, Ontario, annual survivorship for adult Midland Painted Turtles was 0.975 ± (SE) 0.015 for males and 0.985 ± 0.010 for females from 1990 to 2002 (Samson 2003). Juvenile survivorship increased with age and averaged 0.711 ± (SD) 0.134 to 0.747 ± 0.074 for one to three year-olds, and from 0.939 ± 0.031 to 0.967 ± 0.028 for four to seven year-olds in Algonquin Park (Samson 2003).

Numerous studies of Painted Turtles exist, but relatively few can provide reliable estimates of sex ratios because few have absolute estimates of abundance and trapping methods are biased (Ream and Ream 1966; Vogt 1979). The sex ratio of our population was female biased (males/females = 0.53), but within the range of normal fluctuations for a small population of Painted Turtles. The sex ratio of a small population (15–37 adults) in Long Island averaged 0.98 (male/female) over 18 years but fluctuated from 0.36 to 1.91 (Zweifel 1989).

Juveniles are well represented in our population, which demonstrates nesting and hatching success. Our adult:juvenile ratio was 0.9:1, which is lower than the average from Zweifel (1989) long-term study in Long Island (2.16:1), and lower than most Painted Turtle populations studied elsewhere (range 0.67:1 to 5.0:1, reviewed in Zweifel 1989). Lindeman (1996) reported a high proportion of juveniles for Western Painted Turtles at a wastewater lagoon site in Idaho (0.75:1 adult:juvenile). Lindeman (1996) speculated that the high proportion of juveniles at their site could be because their site (1) was recently colonized (18 years) and possibly still growing; (2) had low nest predation rates (zero of 13 nests depredated); and/or (3) had relatively large clutch sizes, high growth rates, and early maturity due to nutrient enrichment and food availability. A high proportion of juveniles may indicate a growing population (de Lathouder *et al.* 2009), but this may not be the case at our site considering the small population size, low density, and presence of several very large (presumably old) individuals. Our population has a slightly unusual pattern of size structure suggesting that young adults are somewhat underrepresented. We do not have the data to assess this further, but it could be possible that young naïve adults exploring their environment move to population sinks, such as lakes that are more frequented by the public or travel onto roads. Younger turtles have a disadvantage because they do not possess knowledge of the locations and relative quality of ponds withing the immediate landscape (Zweifel 1989; Bowne *et al.* 2006).

Population density was 6.5–10 turtles/ha at our site, which is lower than 10 wetlands examined in the USA (25–838 turtles/ha; Ernst *et al.* 1994). The low density may be a result of living close to the northern limit of its range or because urban populations face many challenges (Conner *et al.* 2005; Budischak *et al.* 2006; Peterman and Ryan 2009). Research investigating small populations have significant value because as species declines continue, small populations will become more common. Changes in environmental conditions, such as low water levels, may become more frequent as a result of rapid climate change and can place turtles at increased risk of stochastic events (e.g., mass mortality predation events) that can have long lasting detrimental impacts on species with slow life histories (Keevil *et al.* 2018; Gasbarrini *et al.* 2021). The persistence of these fragments will be important for conserving genetic diversity. Despite increased risk of extirpation, small populations do occur and persist; Zweifel's (1989) long-term study population of Eastern Painted Turtles in Long Island ranged in population size from 21–57 turtles and only 9–14 adult females over the 18-year study. Shoemaker *et al.* (2013) estimated that Bog Turtle (*Glyptemys muhlenbergii*) populations containing a minimum of 15 adult females would have >90% probability of persisting for >100 years. However, that estimate of persistence may be a gross overestimate because demographic and environmental stochasticity, loss of genetic variability, and catastrophes were not taken into account in these models (Reed and McCoy 2014). Despite the small population size and absence of nearby rescue populations, the Rockwood Park population appears to have high survivorship rates (at least for some adults) and demonstrated nesting/hatching success, and provides unique conservation value being an urban population at the northern limit of its range and home to the five largest Eastern Painted Turtles recorded to date.

## Author Contributions

Conceptualization: C.L.B.; Investigation: C.L.B. and S.A.S.; Data Curation: C.L.B. and S.A.S.; Project Administration: C.L.B.; Writing – Original Draft: C.L.B.; Writing – Review & Editing: C.L.B. and S.A.S.; Visualization: C.L.B.; Funding Acquisition: C.L.B.

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## Supplementary Materials:

**TABLE S1.** Input values used to calculate population size estimates for male, female, and juvenile Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick, from 2014–2016.

**TABLE S2.** Jolly-Seber estimates for the proportion of the Eastern Painted Turtle (*Chrysemys picta picta*) population in Rockwood Park, New Brunswick marked in sample two (Spring 2015), sample three (Late Summer 2015), and sample four (Spring 2016).

**TABLE S3.** Straight midline carapace length growth (cm) for Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick over (1) an annual period from Late Summer 2014 to Late Summer 2015 or Spring 2015 to Spring 2016; (2) overwinter period from Late Summer 2014 to Spring 2015 or Late Summer 2015 to Spring 2016; and (3) summer period from Spring 2015 to Late Summer 2015 or Spring 2016 to Late Summer 2016.

**TABLE S4.** Statistical significance (*P*) for annual, overwinter, and summer growth of Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick from a multivariate Generalized Linear Model with normal distribution and identity link function for the dependent variables.

**TABLE S5.** Statistical significance (*P*) of sampling session, sex/age, and straight midline carapace length (MCL) of Eastern Painted Turtle (*Chrysemys picta picta*) captured in Rockwood Park, New Brunswick from a multivariate Generalized Linear Model with normal distribution and identity link function for the dependent variable weight.

**TABLE S6.** Surface water chemistry of Crescent Lake, 19 August 2008 (unpubl. data from Atlantic Coastal Action Plan Saint John).

**FIGURE S1.** Weight and straight midline carapace length of adult male and female and juvenile Eastern Painted Turtle (*Chrysemys picta picta*) captured in Rockwood Park, New Brunswick.

**FIGURE S2.** Straight midline carapace length for each age class of juvenile Eastern Painted Turtle (*Chrysemys picta picta*) captured in Rockwood Park, New Brunswick.