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Cover Photograph: Hatchling *Chrysemys picta* (Painted Turtle) photographed in Brampton, Ontario, Canada. Photographed by Tharusha Wijewardena.

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Altered Hatching Phenology of *Chrysemys picta* (Painted Turtles) and Unusual Terrestrial Observations of *Chelydra serpentina* (Common Snapping Turtles) in Urban Areas in Ontario, Canada

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Abstract - Urbanization and climate change can alter the phenology of freshwater turtles, whose life histories are strongly tied to seasonal temperatures. In cold climates, the severity and duration of winter conditions make emergence and overwintering challenging for freshwater turtles. In Canada, *Chrysemys picta* (Painted Turtles) can either emerge from nests in the autumn, or in the following spring if they overwinter terrestrially, while *Chelydra serpentina* (Common Snapping Turtles) emerge from nests in the autumn and overwinter in thermally stable aquatic habitats. Emergence or overland movement during winter is atypical and often fatal. Through community science programs (2021–2024), we documented unusual winter nest emergences of Painted Turtle hatchlings, and atypical overland movements of Common Snapping Turtle hatchlings, in urban southern Ontario, Canada. These events coincided with warmer winter temperatures, rainfall, and reduced snowfall, which are conditions associated with climate change and urban heat islands. Although Painted Turtles have physiological adaptations such as supercooling and freeze tolerance, frequent freeze-thaw cycles could undermine successful overwintering. In contrast, Common Snapping Turtles cannot survive terrestrial subzero temperatures. Our observations suggest a mismatch between environmental cues and optimal emergence timing, highlighting the need for studying variation in nest emergence and overwintering behavior under altered thermal regimes.

Introduction

Anthropogenic drivers, including urbanization and climate change, can alter local climatic conditions (e.g., temperature and precipitation), causing additive or interactive effects (Chapman et al. 2017, Qian et al. 2022) that influence wildlife (Johnson and Munshi-South 2017, Mawdsley et al. 2009, Urban et al. 2024). Known effects can include shifting population sizes and structures, changes to range limits, and altered breeding and hibernating cycles (Araújo et al. 2006, Elmberg et al. 2024, Lowe 2012, Roberts et al. 2023, Santoro et al. 2023). Ectothermic herpetofauna are sensitive to these effects because their life histories are strongly tied to seasonal thermal conditions (Mi et al. 2022, Santoro et al. 2023). For example, many turtle species have temperature-dependent sex

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determination (Ernst and Lovich 2009). Therefore, warming temperatures and greater thermal fluctuations associated with urban heat islands (Tam et al. 2015) or climate change could alter offspring sex ratios (Janzen 1994, Roberts et al. 2023, Valenzuela et al. 2019). Biased sex ratios can be problematic for long-term population viability because they can limit mate encounter rates and decrease reproductive success (reviewed in Kappeler et al. 2023). Geographical and elevational range shifts are also predicted worldwide in response to urbanization (Johnson and Munshi-South 2017) and climate change (Duan et al. 2016, Forero-Medina et al. 2011, Jiang et al. 2023), which might result in herpetofauna occupying unfavourable habitats. Other examples of predicted climate change impacts include shifts in breeding and hibernating cycles in temperate snakes and frogs (Todd et al. 2011, Turner and Maclean 2022), which could lead to problematic outcomes in terms of predator-prey interactions, breeding phenology, and survival. Overall, anthropogenic drivers that cause warmer environments (e.g., climate change and urban heat island) are likely to have long-lasting impacts on herpetofauna.

Within herpetofauna, freshwater turtles typically display high adult survival but low egg and hatchling survival (Congdon et al. 1987, Ernst and Lovich 2009). Yet, shifts in temperature regimes can impose challenges to the early life stages of turtles, especially during winter (Butler 2019, Gibbons et al. 2000, Stanford et al. 2020). Freshwater turtles living in cold climates that experience winters with extended periods (several months) of subzero temperatures display inter- and intra-specific variation in emergence timing and overwintering strategies (Gibbons 2013; Lovich et al. 2014; Riley et al. 2014, 2020). Hatchlings of several freshwater turtle species like *Chrysemys picta* Schneider (Painted Turtles) and *Graptemys geographica* LeSueur (Northern Map Turtles) spend the first winter of their life in underground nest chambers, surviving freezing temperatures through physiological means, such as supercooling and freeze tolerance (Baker et al. 2003, Gibbons 2013). However, in other species (e.g., *Chelydra serpentina* L. (Common Snapping Turtle), hatchlings exit the nest in the fall and enter an aquatic environment that remains above freezing throughout the winter (Costanzo et al. 1995, Gibbons 2013). There are also documented instances of hatchlings leaving the nest but overwintering on land before entering an aquatic habitat in the spring (e.g., *Emydoidea blandingii* Holbrook (Blanding's Turtle), Paterson et al. 2012). Thus, freshwater turtles in cold climates display remarkable variation in early life overwintering strategies via nest emergence timing (Ultsch 2006).

Given such variations in emergence timing, the cues that trigger the hatchling emergence of freshwater turtles have been an area of active research (Doody 2011; Murphy et al. 2020; Riley et al. 2014, 2020). Decades of research suggest abiotic factors (such as temperature and rainfall; DePari 1996, Santoro et al. 2023) and biotic factors (such as embryo-embryo communication) might trigger hatchling emergence (Doody et al. 2012). For freshwater turtles inhabiting northern range limits, ensuring optimal timing of hatchling emergence is critical to maximize their survival and avoid dangerous climatic conditions (e.g., freezing winter temperatures). Although the exact mechanism of how abiotic factors trigger hatchling emergence is unknown, presumably hatchlings display emergence strategies that maximize their fitness.

Among urban freshwater turtles, Painted Turtles are the most widespread native turtle in Canada and can be found in a wide variety of freshwater habitats including wetlands, creeks, rivers, and lakes (Ernst and Lovich 2009). These turtles are listed as 'Special Concern' (COSEWIC 2018) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Across their range, Painted Turtles typically have an incubation period of 65–90 days, after which hatchlings emerge from their nests (Ernst and Lovich 2009).

Hatchlings can either emerge in the fall or the following spring (Lovich et al. 2014, Riley et al. 2014). Any emergences outside of these months are considered atypical, because the temperature is often below 0 °C and may result in mortality of hatchlings (Costanzo et al. 2008). Hatchlings overwinter in terrestrial nest cavities that are up to 10 cm deep and are exposed to subzero temperatures (-5 °C to -11 °C) throughout winter (Costanzo et al. 2008, Riley et al. 2014). Painted Turtle hatchlings have a remarkable physiological ability to overcome freezing temperatures through freeze tolerance or supercooling, depending on the microenvironmental conditions of the nest (Costanzo et al. 2008). Supercooling occurs when hatchlings maintain body fluids in liquid state, even if the body temperature drops below the freezing point of the tissue, which is approximately -0.6 °C in Painted Turtles (Costanzo and Lee 2013). These hatchlings are also able to tolerate freezing of their tissues down to -4 °C (Costanzo et al. 2000a). Thus, supercooling is effective for surviving occasional extreme cold conditions (-15 °C to -20 °C) during winter. However, soil composition could create ice nucleating agents that trigger freezing and potentially limit the supercooling ability of hatchlings (Costanzo et al. 2000b). Lab-based studies have demonstrated that hatchling Painted Turtles can exhibit occasional movements of head and limbs even at temperatures as low as -10 °C (Costanzo et al. 1999), further underscoring their physiological plasticity. The cold hardiness of Painted Turtles is an active area of research, and it is currently unknown whether hatchlings can switch between either strategy (i.e., supercooling vs. freeze-tolerance) multiple times during a single winter. These limitations highlight how freeze-thaw cycles during winter due to urban heat islands and climate change could impact turtle survival.

Another commonly found urban freshwater turtle is the Common Snapping Turtle. They are the largest freshwater turtle in Canada and occupy a wide range of habitats including ponds, wetlands, sloughs, river edges, and slow streams (Ernst and Lovich 2009). In Canada, they are listed as ‘Special Concern’ (COSEWIC 2008) by COSEWIC. Their overwintering habitats include spring seeps and shallow waters (Ultsch et al. 2007). Importantly, Common Snapping Turtles do not have similar physiological abilities to Painted Turtles to survive subzero temperatures (Costanzo et al. 2008). Most hatchlings are assumed to overwinter aquatically once they emerge from nests in the autumn, but some may spend extended periods of time on land before entering the water (Ernst and Lovich 2009, Ultsch et al. 2007). Some hatchlings may even move between aquatic and terrestrial systems but typically arrive and remain at their overwintering sites by November (Ultsch et al. 2007). A lab-based study showed that hatchlings sometimes exhibit spontaneous locomotor activity when chilled but die by freezing within 20–40 minutes (Costanzo et al. 1999), potentially highlighting the need to find stable aquatic overwintering conditions as fast as possible, or risk mortality. Currently, we have a very limited understanding of post-emergence behavior of Common Snapping Turtles, especially in their northern range margin. It is not surprising that observations of Common Snapping Turtle hatchlings above ground during winter have not been previously documented in Canada.

Ongoing global climate change reduces the predictability of weather conditions, thereby making it more difficult for animals, including turtles (Janzen et al. 2018), to engage in behaviors that optimize fitness (reviewed in Williams et al. 2015). Notably, temperate regions are predicted to have both warmer winters and larger variations in weather patterns, resulting in increased incidences of freeze-thaw cycles (e.g., winter weather whiplash; Francis et al. 2022). These impacts of climate change are not uniform across all land use types; there is a pattern across an urban-rural gradient, with urban areas experiencing greater temperature increases due to urban heat island effects, which consequently amplify climate change impacts (Chapman et al. 2017, Wang et al. 2016). For example, the average global temperature was 1.1 °C higher in 2011–2020 compared to pre-industrial (1850–1900) levels (IPCC 2023), and urban heat islands can increase daytime temperature in cities by 2–7 °C, depending on the region (Peng et al. 2012). Although the impact of climate change on hatching phenology of turtles in urban areas is not well understood, field observations suggest that hatchlings in urban areas could experience a mismatch between environmental cues and optimal emergence timing. Such mismatches could result in turtle hatchlings exhibiting novel or unusual behaviors that lead to detrimental fitness consequences (Warner 2014), such as early emergence during a temporary winter thaw event misinterpreted by hatchlings as the spring.

We describe unusual emergence patterns of Painted Turtle hatchlings and unusual terrestrial movement of Common Snapping Turtle hatchlings during winter within urban areas in southern Ontario, Canada. The winter temperatures in this region historically remained below zero from December to March, however, in recent years, temperatures have begun to fluctuate above zero during winter (Environment and Climate Change Canada 2025). Hatchling observations were made by well-established community science volunteers in the region, who conduct routine annual monitoring of the local freshwater turtle populations. We hypothesized that non-typical hatchling emergence and terrestrial movements during the winter months were a result of unusually warm weather and changes in precipitation patterns. We predicted that hatchling emergences and overland observations coincide with extremes in temperature and rainfall (i.e., warm temperatures caused a melt event and/or rain that flooded nests). Herein, we explore unprecedented reports of turtle hatchlings in Ontario during winter (December–March) and qualitatively assess trends in weather to explore our hypothesis and predictions (i.e., the potential relationship between unusual hatchling behaviors and environmental variables).

Materials and Methods

Study areas

Our main study areas included Heart Lake Conservation Area, Donnelly East Park, and Etobicoke Creek Trail in Brampton, Ontario, Canada (Fig. 1). Each of these 3 sites was routinely monitored for turtle nest activity (see below). These sites are all surrounded by residential and commercial properties, but also include highly fragmented forest patches, ponds, and a network of major roads and highways. Heart Lake Conservation Area is ~170 ha in size and hosts several recreational activities, including fishing, treetop trekking, canoeing, hiking, picnics, and day camping that occur from spring to fall (Heart Lake Conservation Area Master Plan Advisory Committee 2006). Donnelly East Park is ~6 ha in size and common recreational activities within the parkland include baseball games and dog-walking (Pacer 2023). Etobicoke Creek Trail is ~14.5 km in length and includes a mix of urban and natural areas (Ontario Trails Council 2024). Recreational activities in the area include hiking, fishing, and mountain biking. Outside of these routinely monitored areas, we also collected data from nearby municipalities (Toronto, Halton Hills, and Erin), where there were reported opportunistic sightings of turtles in parks and other public properties during winter (Fig. 1).

Survey protocol

Heart Lake Conservation Area, Donnelly East Park, and part of Etobicoke Creek Trail (~7 km) have been routinely monitored for nesting freshwater turtles since 2021, as part of a turtle nest protection program led by a volunteer community science group (Heart Lake Turtle Troopers). Survey efforts are high (i.e., daily surveys) during nesting season and hatchling emergence. Volunteers conduct surveys in the early morning and evening by searching for nesting turtles and turtle nests in the area. Once a nesting turtle is observed, volunteers maintain a safe distance from the turtle (> 5 m) and monitor the turtle until nesting is completed. Within 24–48 hours of oviposition, volunteers place a nest protection box (60x60 cm with 4 exit holes; steel mesh diameter = 1.3 cm) over the nest using 30-cm nails to protect eggs from predators. Typical mammalian predators of turtle eggs in surveyed areas include *Canis latrans* Say (Coyote), *Neogale vison* von Schreber (American Mink), *Procyon lotor* L. (Raccoon), and *Vulpes vulpes* L. (Red Fox). Nest protectors were also placed on suspected nests after carefully digging the nest for confirmation of eggs. Nests that were in vulnerable locations (e.g., roadside, private properties) were excavated and sent to Scales Nature Park in Oro-Medonte, Ontario, Canada. During winter (i.e., the period when precipitation is expected to be snow and temperatures are consistently below zero; December-March), nest protectors were removed by volunteers if they impeded snow removal by city staff. These nest protectors were reinstalled in spring following the final snow melt (typically in early-mid April) to ensure maximum protection for the hatchlings. During winter, monitoring occurs less frequently, but volunteers typically visit sites at least once a week to ensure nests are safe from predators and anthropogenic disturbances. During the winter months, volunteers continue to observe and record data on nest conditions and the emergence of hatchlings.

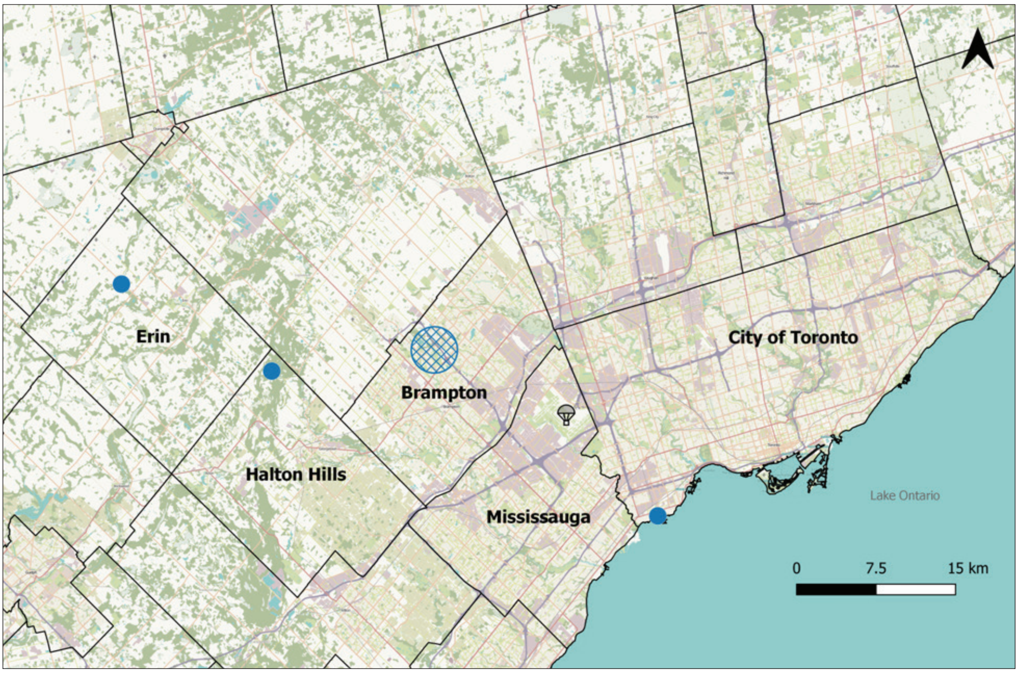

Figure 1. Locations of unusual winter emergences of *Chrysemys picta* (Painted Turtles) and unusual overland observations of *Chelydra serpentina* (Common Snapping Turtles) during winters 2022–2024 in Ontario, Canada. Gridded blue circle indicates areas that are routinely monitored by Heart Lake Turtle Troopers in Brampton. Solid blue circles indicate opportunistic sightings by volunteers. Grey parachute indicates location of the weather station. Solid black lines indicate lower municipalities in Ontario.

Climate data

We extracted daily weather data from 2013 to 2024 from the Government of Canada website (https://climate-change.canada.ca/climate-data/#/daily-climate-data; ClimateID 6158731). Weather data including location, mean daily temperature (°C), total daily rainfall (mm), and total daily snow (mm) were obtained from the weather station at the Toronto Pearson International Airport. We classified records from 1 November 2013 to 31 March 2022 as historic, as prior climate data was unavailable from this station, and calculated the mean for each metric. Then, we obtained the same weather metrics separately for 2022/2023 and 2023/2024 winters. We used R (R Core Team 2021) and 'ggplot2' package (Wickham 2016) to generate means for historic data and associated figures. We did not conduct any statistical analyses due to the small sample size of Painted Turtle (n = 5) and Common Snapping Turtle (n = 3) observations and the lack of systematic survey effort in all study areas.

Results

Observed nests

Since 2021, Heart Lake Turtle Troopers have protected Painted Turtle and Common Snapping Turtle nests in 3 urban parks in Brampton, Ontario, Canada. Similar to emergence patterns observed in other areas of southern Ontario, Painted Turtle hatchlings in Brampton either emerge in the autumn or spend winter in underground nest cavities and emerge from early April onwards (Table 1). In the winter of 2021/2022, volunteers observed typical emergence patterns in Painted Turtle hatchlings (Table 1), whereas in the winters of 2022/2023 and 2023/2024, they observed unusual emergence patterns and unusual overland movements (Table 2).

Summer 2022. From 21 May 2022 to 5 July 2022, volunteers installed nest protectors on 63 Painted Turtle nests in Brampton. They excavated eggs from 21 Painted Turtles nests due to risk to the nests (see risks outlined in the Materials and Methods) and sent them for artificial incubation between May and July. In Painted Turtles, emergence holes were observed in 15 nests in April and 11 additional nests in May.

Summer 2023. From 29 May 2023 to 7 July 2023, volunteers installed nest protectors on 89 Painted Turtle nests. Due to potential risks to the nests, eggs from 37 Painted Turtle nests were excavated and sent to Scales Nature Park for artificial incubation between June and early August. Of the remaining Painted Turtle nests, emergence holes and eggshells were observed within 2 nests in September and 2 nests in October, indicating natural emergence.

Unusual emergence patterns and terrestrial movements of Painted Turtles

During the 2022/2023 winter, volunteers observed emergence holes in 1 Painted Turtle nest in January, and 3 additional Painted Turtle nests in February in routinely monitored areas. However, no hatchlings were observed in the immediate vicinity. Given that volunteers routinely monitor these areas, it is unlikely that emergence holes appeared in the autumn and were missed. Thus, we presume that approximately 6% (n = 4/68) of Painted Turtle nests in Brampton showed atypical emergence patterns based on emergence holes.

During the 2023/2024 winter, a volunteer observed a Painted Turtle hatchling near a nest protector in a routinely monitored area in Brampton in late December (Table 2). Then, in January, another volunteer hiking in the area opportunistically observed at least 7 Painted Turtle hatchlings in the Terra Cotta Conservation Area in Halton Hills. Although there was no nest protector in this area, given the number of hatchlings observed, we considered that these hatchlings emerged from a nearby nest. In early March, hatchlings were observed on land near 3 additional nests in routinely monitored areas in Brampton (Table 2). On all occasions, the hatchlings were found to be cold and lethargic (Fig. 2). Thus, volunteers provided warmth to the hatchlings by holding them in their hands, and once their condition improved, the volunteers released the hatchlings into the nearest wetland. As the season progressed, emergence holes were observed in 8 additional Painted Turtle nests in March, and 4 of these nests also still had hatchlings within them. Thus, in Brampton, about 4% (n = 4/89) of Painted Turtle nests showed unusual emergence patterns, with emergence starting about a month earlier than expected (i.e., in March vs. April).

In April, emergence holes were observed in 11 nests, and 9 of these nests still held at least 1 hatchling; hatchlings emerging in April is not unusual in our study site (Table 1). Hatchlings were allowed to leave the nest on their own timing, but if the risk to the hatchling increased (e.g., cold spells, desiccation, predation), volunteers released the hatchling to the nearest wetland. Given that hatchlings did not emerge from 28 nests by mid-May (the typical start period of next season's nesting period), volunteers extracted and released hatchlings following permit guidelines.

Unusual observations of Common Snapping Turtle hatchlings

Common Snapping Turtle hatchlings were observed on land in Erin, Toronto, and Brampton areas of southern Ontario in December 2022 and 2023 (Table 3). In December

Table 1. Typical nesting and hatchling emergence period of *Chrysemys picta* (Painted Turtle) and *Chelydra serpentina* (Common Snapping Turtles) in Brampton, Ontario, Canada from 2021 to 2024.

Year	Species	Total number of nests		Nesting period		Typical hatchling emergence period	
		Incubated	In the wild	Start	End	Start	End
2021	Painted	0	36	25 May 2021	08 Jul 2021	*Spring*: 13 April 2022	19 May 2022
	Snapping	0	34	01 Jun 2021	16 Jul 2021	*Fall*: 23 Aug 2021	22 Oct 2021
2022	Painted	21	47	21 May 2022	05 Jul 2022	*Spring*: 4 April 2023	28 May 2023
	Snapping	36	37	6 Jun 2022	17 Jul 2022	*Fall*: 18 Aug 2022	25 Sep 2022
2023	Painted	37	52	29 May 2023	07 Jul 2023	*Fall:* 12 Sep 2023	15 Oct 2023
						Spring: 5 Apr 2023	22 May 2024
	Snapping	53	29	03 Jun 2023	09 Jul 2023	*Fall:* 02 Sep 2023	17 Oct 2023

2022, 1 hatchling was observed on a paved path near a library in Erin. It is unclear whether the hatchling emerged from a nearby nest, was on route to water, or returned to land from water. In December 2023, 1 hatchling was observed on land in a public park in Toronto, and another hatchling was observed near a trail path in Brampton. However, the volunteers were unable to locate the nests. Regardless of whether these observations are considered emergences or overland movements, it is highly unusual to observe hatchlings on land during winter in southern Ontario.

Temperature and precipitation patterns

During 2022/2023 and 2023/2024 winters, atypical emergence patterns were observed in Painted Turtle hatchlings. These observations occurred between December and March, when the historical temperatures were below 0 °C (Fig. 3). With Painted Turtles, we noticed that temperature fluctuations between 0 °C and 10 °C, total daily rainfall up to 12 mm, and lack of snowfall coincided with hatchling emergences (Fig. 3). However, instances of hatchling emergence were not observed with every temperature fluctuation and rainfall event. Similarly, in Common Snapping Turtle hatchlings, over 5 °C winter temperatures, rainfall, and lack of snowfall events coincided with overland observations in December of 2022 and 2023 (Figs. 4A, 4B).

Table 2. Reports of unusual emergence timing of *Chrysemys picta* (Painted Turtles) in the Peel and Halton regions of Ontario, Canada during winter of 2023/2024.

Date	Location	Number observed	Habitat description
30 Dec 2023	Esker Trail, Brampton	1	Found in the field near the nest protector. Hatchling was very cold but was provided warmth by a volunteer prior to release.
5 Feb 2024	Terra Cotta Conservation Area, Halton Hills	7	Hatchlings were observed on land and taken to nearby wetland
3 Mar 2024	Heart Lake Conservation Park, Brampton	1	A hatchling was observed in the nest hole. Either the same hatchling or a different one emerged from the nest and remained inside the nest protector.
10 Mar 2024	Esker Trail, Brampton	11	Two hatchlings were found near the nest. An additional 9 hatchlings discovered near the same nest after 3 days and taken to wetland.
15 Mar 2024	Esker Trail, Brampton	1	One hatchling emerged from nest and remained inside nest protector.

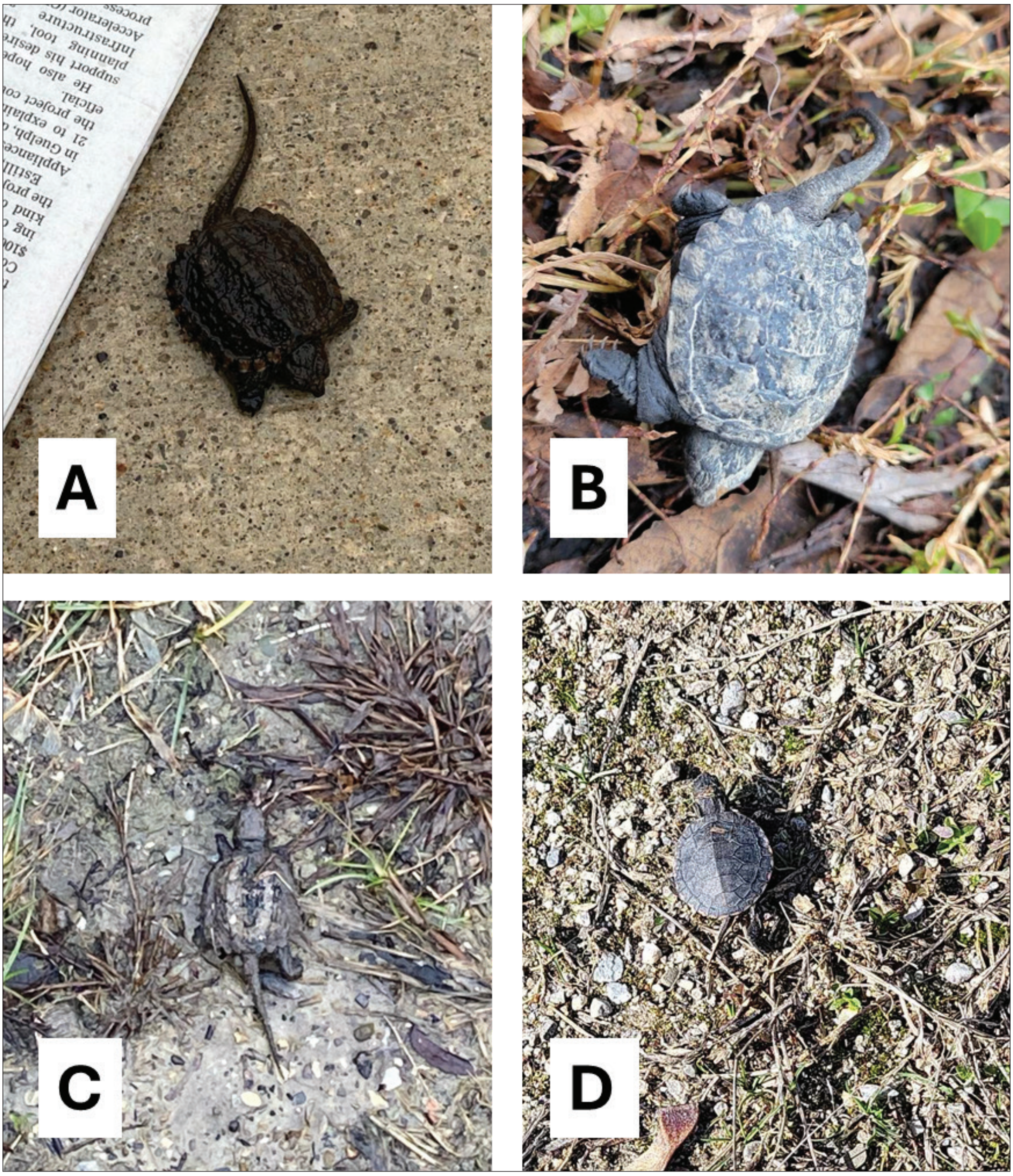

Figure 2. Photographs of hatchling turtles that were observed on land during winter of 2022/2023 and 2023/2024 in Ontario, Canada. A) *Chelydra serpentina* (Common Snapping Turtle) hatchling that was observed on land on 31 December 2022 in Erin. B) Common Snapping Turtle hatchling that was observed on land on 4 December 2023 in the Samuel Smith Park in Toronto. C) Common Snapping Turtle hatchling that was observed on land on 29 December 2023 at Etobicoke Creek Trail in Brampton. D) *Chrysemys picta* (Painted Turtle) hatchling that emerged on 11 March 2024 in Esker Trail of Brampton.

Discussion

Previous surveys in Brampton, Ontario, indicate that Painted Turtles in this area have incubation periods and emergence patterns similar to those described in the literature (Table 1). Yet recently (Table 2), atypical patterns of emergence, often sooner than expected in spring, were observed in ~5% of Painted Turtle nests. Similarly, unusual overland movements were observed in hatchlings of Painted and Common Snapping turtles during winter, potentially highlighting the impact that anthropogenic changes such as urbanization and climate change impose on survival of these ectotherms.

More specifically, in the winters of 2022/2023 and 2023/2024, we observed atypical emergence patterns in Painted Turtles at our study sites in Brampton and surrounding regions. We consider these winters to be anomalous compared to historical weather data, due to temperature spikes, lack of heavy snowfall, and rainfall events from December to March. Our results provide some support to our hypothesis that the hatchlings emerged due to unusually warm weather and unexpected rainfall events during winter. However, similar emergence patterns were not observed at each temperature spike and rainfall event. It is plausible that hatchlings use multiple cues to emerge from nests, and that while these abiotic factors (e.g., increase in temperature and rainfall) do play a role in emergence timing, they are not the only cues that turtles use (Costanzo et al. 2008). Previous work has shown that factors including temperature, precipitation, and presence of within-nest predators (e.g., ants or sarcophagid larvae) can cue nest emergence in hatchlings (Doody 2011, Riley et al. 2014, Santoro et al. 2023), while biological factors such as an "internal clock" or embryo-embryo communication can also trigger emergence in some species (Doody et al. 2012, Lindeman 1991). We did not observe ants or sarcophagid larvae in or near turtle nests, suggesting that these predators are unlikely to be driving unusual hatchling emergence at our sites, further supporting our hypothesis that anthropogenic-induced increase in winter temperatures likely contribute to atypi-

Table 3. Reports of unusual overland sightings of *Chelydra serpentina* (Common Snapping Turtles) in the Toronto and Peel Regions of Ontario, Canada for 2022/2023 winter.

Date	Location	Number observed	Habitat description
31 Dec 2022	Hillsburgh Library, Erin	1	A hatchling was observed on a cement path in front of the library. Hatchling was taken safely to a nearby wetland.
4 Dec 2023	Colonel Samuel Smith Park, Toronto	1	A hatchling was observed on land by a volunteer and taken to a nearby waterway.
29 Dec 2023	Etobicoke Creek Trail, Brampton	11	Observed by volunteer near trail path in unmonitored area. Hatchlings were gone when observed later. Hatchlings likely proceeded to a nearby wetland.

cal hatchling behavior. However, we acknowledge that our sample size is small and the survey effort was not uniform across study areas. Thus, our conclusions are preliminary and require additional research.

Interestingly, in the southern range of many turtle species, hatchling emergence already occurs over a wide breadth of timing (Ernst and Lovich 2009). For example, in species with broad range distributions (e.g., *Trachemys scripta* Thunberg (Pond Slider)),

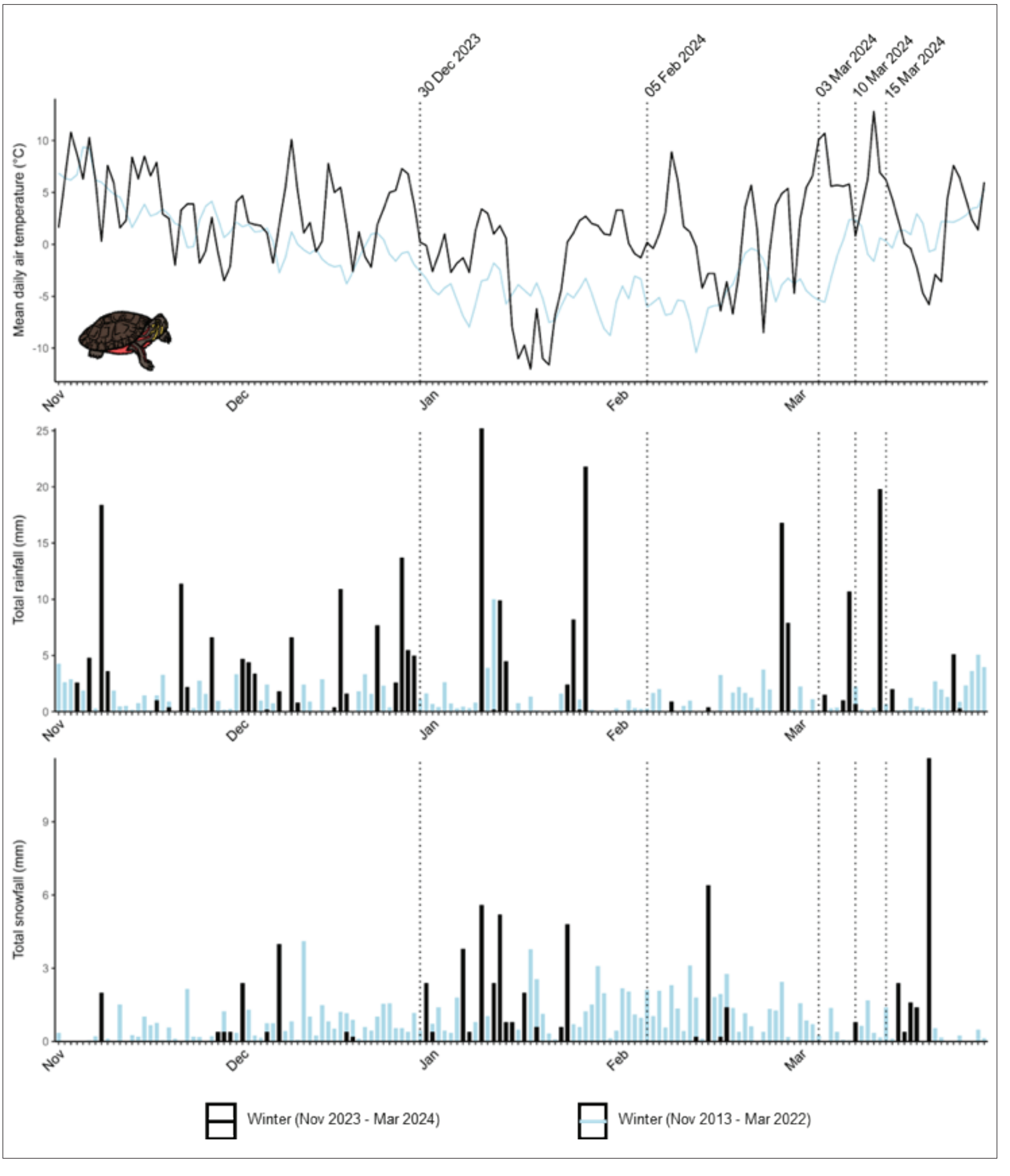

Figure 3. Comparison of daily climatic trends and unusual emergence patterns of *Chrysemys picta* (Painted Turtles) hatchlings in Brampton, Ontario, Canada. Dotted lines refer to unusual emergences from nests. Climatic data were obtained from a single reference station at the Toronto International Airport weather station in Ontario, Canada.

hatchlings emerge during mid-winter in southern geographies like Florida, USA (Aresco 2004). However, this is not the case in our study site, given that winters tend to be long and harsh with 4–6 months of subzero temperatures and heavy snowfall. Painted Turtles also have a relatively broad distribution, but in contrast to Pond Sliders, Painted Turtles in the northern range margin experience stronger selective pressures on overwintering behavior due to freezing temperatures (Riley et al. 2014). Our current understanding of Painted Turtle overwintering physiology dictates that hatchlings remain in well-insulated

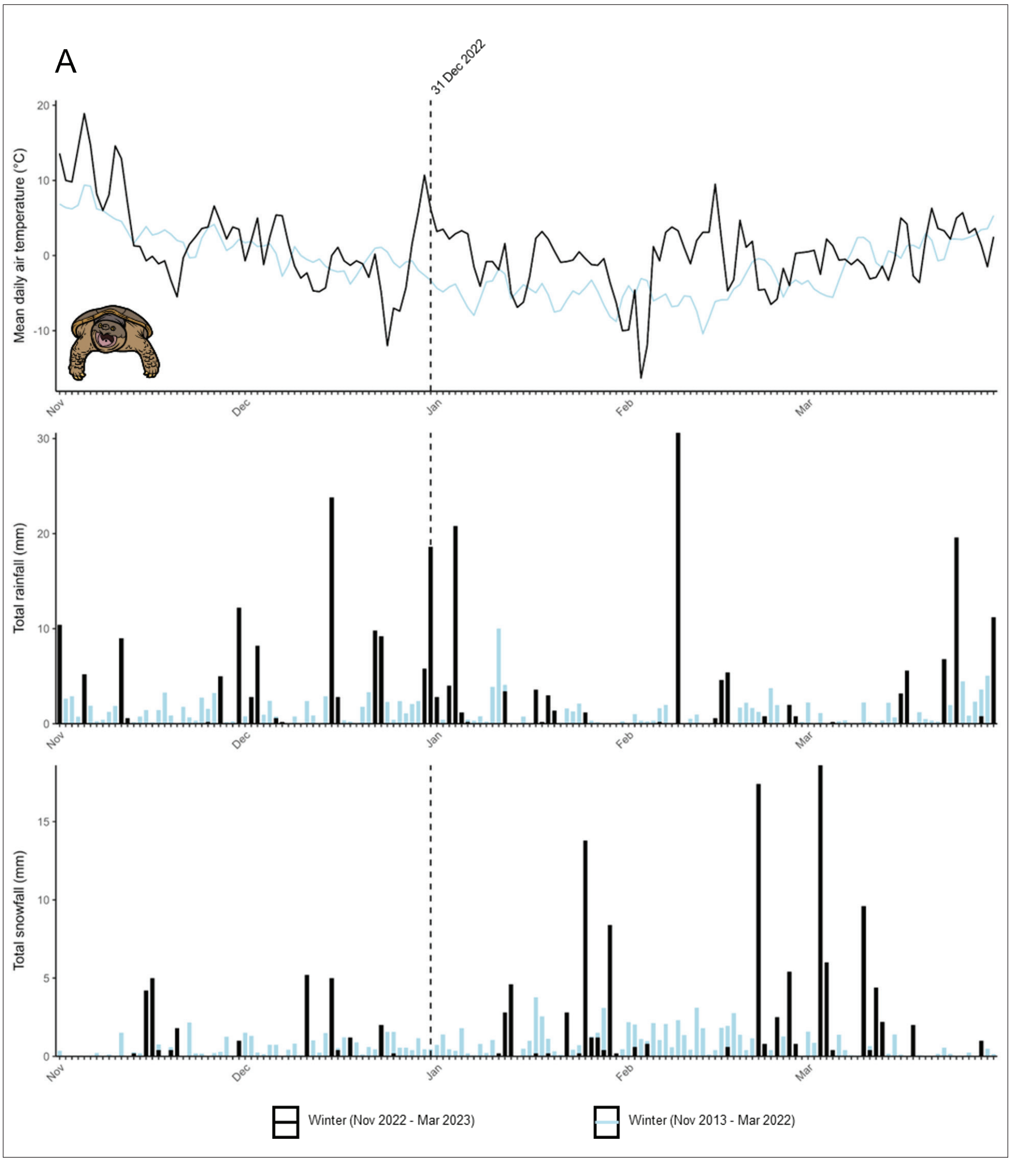

Figure 4. Comparison of daily climatic trends and unusual terrestrial observations of *Chelydra serpentina* (Common Snapping Turtles) hatchlings during winters of 2022/2023 (A) and 2023/2024 (B) in Toronto and Brampton, Ontario, Canada. Climatic data were obtained from a single reference station at the Toronto International Airport weather station in Ontario, Canada.

refugia during winter and are able to survive brief exposure to subzero temperatures (Costanzo and Lee 2013). Thus, although Painted Turtles possess remarkable physiological abilities to survive cold conditions in their northern range margins, the current weather patterns that we now experience in Ontario (e.g., rapid freeze and thaw cycles and lack of snow), especially in urban areas, are likely to impose physiological constraints on hatchlings, potentially increasing winter mortality.

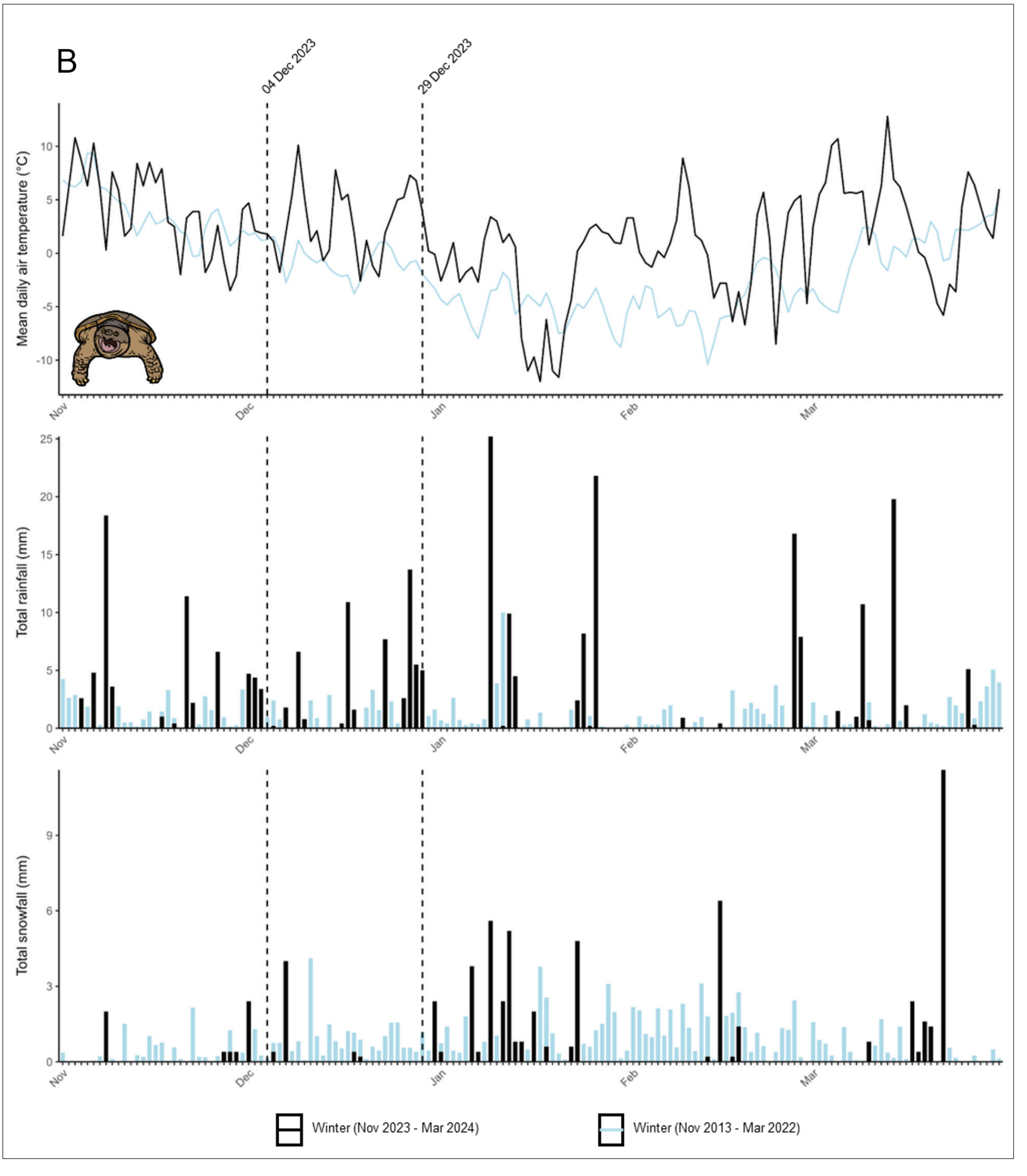

Figure 4. Comparison of daily climatic trends and unusual terrestrial observations of *Chelydra serpentina* (Common Snapping Turtles) hatchlings during winters of 2022/2023 (A) and 2023/2024 (B) in Toronto and Brampton, Ontario, Canada. Climatic data were obtained from a single reference station at the Toronto International Airport weather station in Ontario, Canada.

In contrast to Painted Turtles, Common Snapping Turtles do not possess supercooling or freeze tolerance abilities (Costanzo et al. 2008). There is evidence from central Ontario that a very small percentage of Common Snapping Turtle hatchlings can overwinter terrestrially in the nest chamber and survive the winter if freezing temperatures do not occur (Obbard and Brooks 1981). However, it is highly unusual for Common Snapping Turtle hatchlings to be observed on land in December. With changing climatic conditions, Common Snapping Turtles may engage more frequently in unusual movement behaviors throughout winter, which may result in their increased mortality through freezing and dehydration. In addition, unnecessary terrestrial movements could result in the loss of energy required by hatchlings to survive the winter, even when they have found stable aquatic overwintering environments. Thus, if such behaviors become more common, low recruitment through increased overwintering mortality could slowly impact population persistence, especially in urban areas.

Overall, our study suggests an expansion in the nest emergence timing for Painted Turtles and unusual terrestrial behaviors for Common Snapping Turtles in southern Ontario. It also highlights the importance of recording unusual observations to identify broader geographical patterns of nest emergences and overwintering behavior of freshwater turtles. Very little is known about the post-emergence movements of hatchlings, due to their low survival, technological limitations (e.g., weight of radio-transmitters and short battery life), and lack of research (Ultsch et al. 2007). We expect that similar patterns of unusual movement in urban areas are likely to occur throughout the geographic range of both species. More research on nest emergence timing is required to understand how this behavior may change in response to urbanization and climate change at species' northern range limits. In addition, it is critical to study the survival implications of this novel phenology because exposure of individuals to the strong selective force of freezing winter conditions may be increasing.

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