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Assessing terrestrial movements of Eastern Musk Turtle (*Sternotherus odoratus*) using iNaturalist Canada

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Abstract

Eastern Musk Turtle (*Sternotherus odoratus*) is known to be a highly aquatic species, yet it is occasionally found away from waterbodies. If such movements are common, then road mortality may pose a substantial risk to the species. We examined iNaturalist Canada observations of Eastern Musk Turtle on roads and found 15 in which individuals were >25 m from water. The median distance to the nearest permanent waterbody was 100 m (range 30–330 m). All observations that were ≥100 m from the nearest waterbody occurred from mid-July onward, suggesting that the movements were not related to nesting activity. At least under some circumstances, Eastern Musk Turtle can move >100 m away from waterbodies increasing the risk of road mortality.

Key words: Community science; Eastern Musk Turtle; *Sternotherus odoratus*; iNaturalist; movement; road mortality

Introduction

Eastern Musk Turtle (*Sternotherus odoratus*) is the widest ranging member of the turtle family Kinosternidae and is native to eastern North America (Ernst and Lovich 2009). It is rarely found far from water, and home ranges are often confined to a single waterbody (Ernst and Lovich 2009; Wilhelm and Plummer 2012). The use of multiple waterbodies has been reported, but they are often wet meadows or streams adjacent to a main waterbody (Ernst 1986; Rowe *et al.* 2009). Aquatic movements can exceed 1.5 km along waterways (Laverty *et al.* 2016) but terrestrial movements away from water appear to be uncommon. During one study, none of the radio-tracked musk turtles were found on land (Wilhelm and Plummer 2012). The sporadic drying of relatively permanent wetlands can cause turtles to move to other wetlands; however, Eastern Musk Turtle is more likely to remain in drying wetlands than many other turtle species (Gibbons *et al.* 1983), and the maximum observed terrestrial movement from a seasonal wetland is only 48.7 m (Buhlman and Gibbons 2001). Nesting is usually within 20 m of water (Cagle 1937; Ernst 1986; Edmonds 1998) with a maximum reported distance of 45 m inland (Ernst and Lovich 2009).

Eastern Musk Turtle experiences a higher evaporative water loss rate compared with many other turtle species (Ernst 1968; Murphy *et al.* 2016), and this likely explains at least part of the lack of terrestrial movements. Despite its highly aquatic nature, Eastern Musk Turtle is occasionally found away from water. For example, we found a dead adult Eastern Musk Turtle on a road in eastern Ontario that was 280 m away from aquatic habitat (Seburn and Burns 2021). Another adult Eastern Musk Turtle "was found abroad in a hardwood forest about 396 m from the nearest known body of water" in North Carolina (Palmer and Braswell 1995: 88). Clearly, Eastern Musk Turtle can make substantial movements away from water, at least under some circumstances. It remains unclear how often and how far individuals move away from aquatic habitat.

If Eastern Musk Turtle movements away from aquatic habitat are not rare, then this species may be more at risk from road mortality than is generally believed. Given that Eastern Musk Turtle is a species-at-risk in Canada (SARA Registry 2021), it is important to assess potential threats to it. Although road mortality has been identified as a threat, it was not quantified (COSEWIC 2012). A number of researchers have reported road mortality of Eastern Musk Turtle in Canada (Garrah *et al.* 2015; Choquette and Valliant 2016; Carstairs *et al.* 2018) and in the United States (Smith and Dodd 2003; Aresco 2005; Palis 2021), but typically in low numbers. If terrestrial

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movements are uncommon or of short duration, then they may be difficult to detect through radio-tracking studies, but may be more apparent through opportunistic observations of them found on roads.

To help quantify terrestrial movements in Eastern Musk Turtle, we examined observations from iNaturalist Canada, a community science, or citizen science, platform to record native and exotic species in Canada that includes over nine million observations of more than 34 000 species observed by more than 170 000 people (iNaturalist Canada 2022a). It contains more than 400 observations of Eastern Musk Turtle in Canada with an accompanying photo that has been identified by at least two people (termed "research grade"). Data from iNaturalist have been used to address a variety of spatial questions in ecology, including patterns in urban biodiversity (Callaghan *et al.* 2020) and the distribution of exotic species (Werenkraut *et al.* 2020; Mo and Mo 2022). Using data from iNaturalist Canada is an easy way to assess terrestrial movement over a large area by looking at observations of Eastern Musk Turtle on roads.

Methods

We downloaded observations of Eastern Musk Turtle to the end of September 2022 from the iNaturalist project "Canadian Amphibians and Reptiles on Roads", which was created by the Canadian Herpetological Society. We used the roads project as an unambiguous way to obtain observations of the turtles on land. We recognized that not all Eastern Musk Turtle observations of individuals on roads would have been added to this project, so we also reviewed all other Canadian observations of this species and added relevant ones to the project. Such additions were limited to photos showing an Eastern Musk Turtle that had been hit by a vehicle or observations with notes indicating that the turtle was found on a road.

Given the perceived risk to Eastern Musk Turtle of poaching (iNaturalist Canada 2022b), the locations of observations are obscured on iNaturalist, with a random location mapped within a cell of 0.2° × 0.2° or roughly 20 km × 20 km at mid-latitudes (iNaturalist 2022). Thus, we obtained the private location of all the observations from iNaturalist Canada. Observations lacking any spatial accuracy or with a spatial accuracy >35 m were excluded from analyses, as these points were often distant from roads making it more difficult to estimate the actual location on the road and hence an accurate distance to water. Observations with a spatial accuracy ≤35 m were all within 10 m of a road. We mapped all observations in QGIS 3.4 (QGIS Development Team 2022) and selected those that were at least 25 m from water and determined the straight-line distance to the nearest lake, river, or permanent wetland. Observations <25 m from water were excluded as minor movements away from waterbodies. Lakes, rivers, and streams were visible on aerial imagery, while wetlands were mapped using Ontario GeoHub's wetland layer (Ontario GeoHub 2022). To ensure that our measurement was a conservative estimate of terrestrial movements, we measured the straight-line distance from the edge of the nearest waterbody to the edge of the road nearest the observation and rounded down to the nearest 10 m. To consider the possibility that turtles were moving from one waterbody to another, we also calculated the distance to the next waterbody from the turtle in any direction away from the nearest waterbody. We used Google Street View (Google 2023) to assess habitat adjacent to roads when there was the possibility of a flooded, roadside ditch that could facilitate Eastern Musk Turtle movement. We determined the amount of precipitation over the previous five days at the nearest weather station to each of the Eastern Musk Turtle observations (Government of Canada 2023) that were at least 100 m from the nearest waterbody. We selected a window of five days as freshwater turtles typically do not persist on the road for longer than that (Santos *et al.* 2011).

Results

We found 82 observations of Eastern Musk Turtle on roads. Most of these observations were within 25 m of water, had low spatial accuracy, or the private coordinates were not available. This reduced the dataset to 15 observations of Eastern Musk Turtle on roads that were more than 25 m from any waterbody (i.e., lake, permanent wetland, river) and had a high degree of spatial accuracy (mean ± SD, 13.7 ± 9.7 m). Nine of the 15 (60%) observations were of dead turtles. The 15 observations were widely distributed across eastern and central Ontario, with one in southwestern Ontario (Figure 1). The observations were on 10 different roads, with up to four observations on one road. The road with four observations was parallel to a lake ~2 km in length with several bays that came within 150 m of the road.

The sex and size of most turtles were not available, although all photos showed individuals that were either large juveniles or adults. The turtles were observed from 5 June to 9 August. The median distance from the nearest waterbody was 100 m (range 30–330 m). Eight of the 15 (53.3%) observations were 100 m or more from the nearest waterbody and occurred between 14 July and 9 August. The median distance to the next waterbody for those eight observations was 315 m (range 100–1100 m).

For five of the eight observations ≥100 m from the nearest waterbody, the line from the waterbody to the

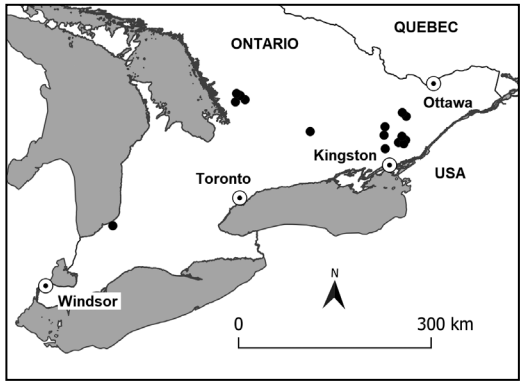

FIGURE 1. Locations of Eastern Musk Turtle (*Sternotherus odoratus*) observed on roads from the iNaturalist Canada project "Canadian Amphibian and Reptiles on Roads". Only observations that were >25 m from any water body and had a high degree of spatial accuracy are mapped. A few overlapping points were shifted slightly to make them visible.

turtle was perpendicular to the road; thus, any movement to the road would have been overland, not in any roadside ditch (Table 1). Of the remaining three observations, the turtle could have moved along a roadside ditch for at least part of the distance from the wetland for two of the observations. In the third observation there was no roadside ditch present and so the turtle likely moved along the road or the road shoulder. The nearest waterbody to five of the observations was permanent (a lake or stream) and, hence, these turtles likely did not move because the waterbody dried up.

Precipitation data were missing for one of the eight observations, but all but one of the other seven observations had precipitation during the five days preceding the observations, suggesting that rain could have triggered the terrestrial movement of the turtles. The average amount of precipitation was 1.5 cm (range 0.4–2.9 cm). For the three turtles found alive on roads, there was precipitation on two of those three days. For the third turtle found alive there was no precipitation the day it was found on the road or on the preceding five days.

Discussion

Data from iNaturalist yielded 15 observations of Eastern Musk Turtle at distances >25 m from waterbodies, with one turtle observed more than 300 m from water. Our measurements of terrestrial movement may underestimate actual movements as we assumed the turtles came from the nearest waterbody to the road. This was likely true, but in a few instances, the nearest waterbody, as determined by Google imagery and the wetland layer, was a small wetland with no open water habitat but a larger waterbody was farther away.

Movements away from water can occur among adult females looking for places to lay their eggs. Although documented Eastern Musk Turtle nests are typically <45 m from water (Ernst and Lovich 2009), it is possible that some females may move longer distances to nest. The fact that all of the longest terrestrial movements were found from mid-July to August suggests that they were not related to nesting, as nesting by this species in northern areas is generally in June or early July (Ernst 1986; Laverty 2010). For five of the eight observations with the longest overland movements, the turtles were found dead, so it is possible that they were killed by vehicles some time before they were observed, although turtle carcasses typically do not persist on roads for more than five days (Santos *et al.* 2011), so it is unlikely these turtles were seeking nesting sites. If these turtles were not moving for nesting purposes, then their movement between waterbodies may have been related to

TABLE 1. Habitat characteristics associated with Eastern Musk Turtle (*Sternotherus odoratus*) observations at least 100 m from a waterbody.

Turtle no.	Distance to water, m	Type of waterbody	Orientation*	Roadside ditch†
1	100	Lake	Perpendicular	Present
2	100	Marsh	Parallel	Shallow and rocky
3	250	Swamp and creek	Parallel	Present
4	330	Marsh	Perpendicular	Present
5	100	Stream	Parallel	None
6	150	Lake	Perpendicular	Present
7	230	Lake	Perpendicular	Present
8	110	Lake	Perpendicular	Present

*Orientation of the water body relative to the location of the turtle on the road. Perpendicular: the shortest straight line from the water body to the turtle is perpendicular to the road. Parallel: the turtle was found down the road from the water body.
†Assessed using Google Street View.

dispersal or seasonal movements. The median distance to the next waterbody was over 300 m indicating that, if these movements were from one waterbody to another, then the turtles are moving hundreds of metres overland.

Eastern Musk Turtle is known to make use of flooded roadside ditches (Berry 1975), although it is unclear how often this occurs. The eight turtles observed ≥100 m from a waterbody were all found in July or August, and it is unlikely that roadside ditches were flooded at that time of year. The nearest waterbody to five of these eight turtles was permanent (Table 1) suggesting that the turtles were not forced to move because the water dried up. The turtles may have moved overland in association with rainfall events, as it rained before most of the observations in which turtles had moved at least 100 m. Eastern Musk Turtle is known to have a high rate of evaporative water loss (Murphy *et al.* 2016), so it is not surprising that terrestrial movements would be related to rainfall.

It remains unclear how often Eastern Musk Turtle moves >25 m away from waterbodies and the purpose of these terrestrial movements. The fact that individuals were found on roads >25 m from water in various parts of Ontario (Figure 1) suggests that such movements are widespread, although not likely common. Although the observations were widespread, some of them were also clustered, which may suggest longer terrestrial movements are correlated with certain habitat configurations. It is also possible that clustered points are an artifact of sampling biases in the iNaturalist data. Additional research on terrestrial movements of Eastern Musk Turtle is warranted to better understand the spatial ecology of this species and the risks that road mortality and terrestrial habitat development may pose.

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